

**Institution for the Use of Groundwater in Assam:
A Study of Groundwater Markets with Special Emphasis
on Structure, Determinants, Reliability and Efficiency**

A thesis submitted to Indian Institute of Technology Guwahati
in partial fulfilment of the requirements for the degree of
Doctor of Philosophy



By

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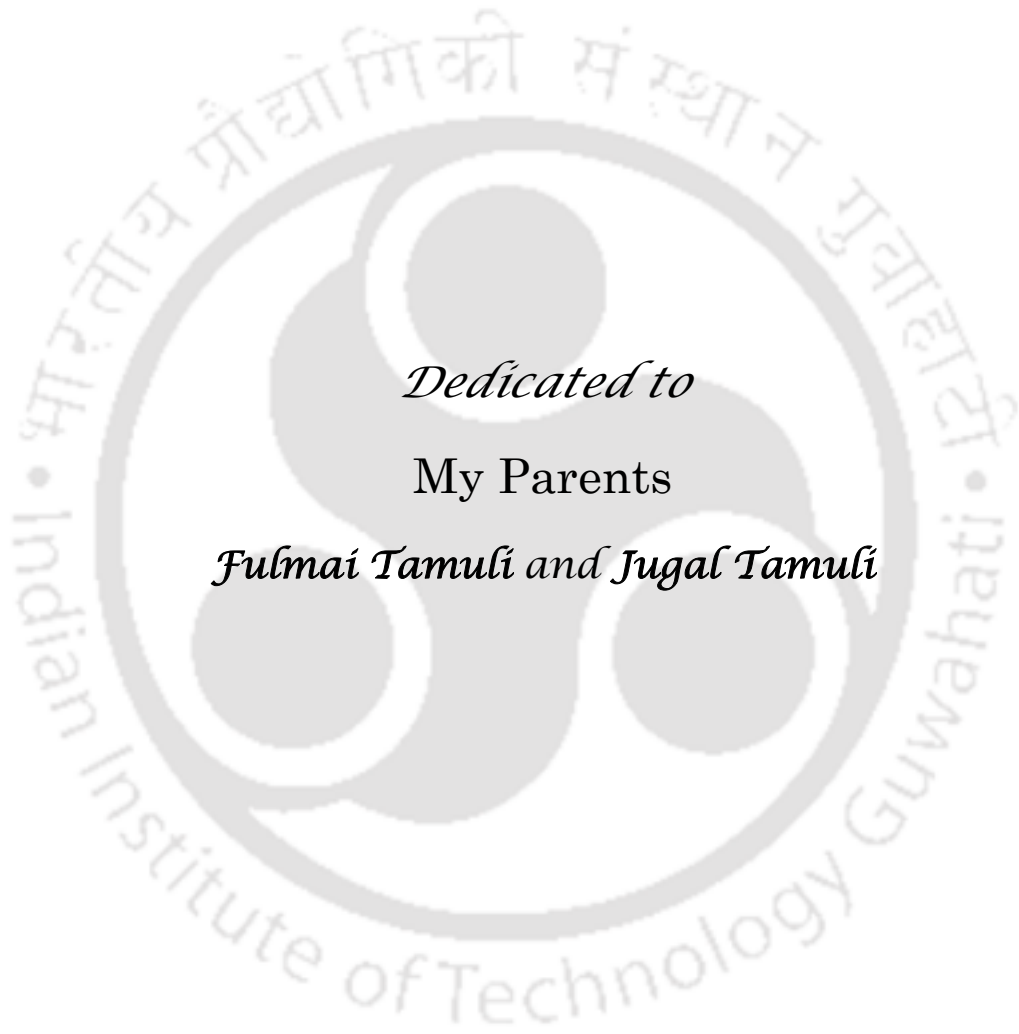
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India

March 2014





Dedicated to

My Parents

Fulmai Tamuli and Jugal Tamuli





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Declaration

I hereby declare that the thesis entitled “**Institution for the Use of Groundwater in Assam: A Study of Groundwater Markets with Special Emphasis on Structure, Determinants, Reliability and Efficiency**”, is the result of investigation carried out by me in the Department of Humanities and Social Sciences, Indian Institute of Technology Guwahati, India, under the supervision of Dr. Mrinal Kanti Dutta, Associate Professor (Economics), Department of Humanities and Social Sciences, IIT Guwahati.

In keeping with the general practice of reporting scientific observations, due acknowledgement has been made wherever the work described is based on the findings of other investigations.

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Certificate

This is to certify that the thesis entitled “**Institution for the Use of Groundwater in Assam: A Study of Groundwater Markets with Special Emphasis on Structure, Determinants, Reliability and Efficiency**”, submitted by Mr. Jitu Tamuli for the degree of Doctor of Philosophy in Economics in the Department of Humanities and Social Sciences of Indian Institute of Technology Guwahati, embodies bonafide record of research work carried out under my supervision and guidance. The collection of materials/data from the secondary and the primary sources has also been done by Mr. Jitu Tamuli himself.

The present thesis or any part thereof has not been submitted to any other University for award of any degree or diploma.

All assistance received by the researcher has been duly acknowledged.

(Mrinal Kanti Dutta)
Supervisor



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Abbreviation

AACP	: Assam Agricultural Competitiveness Projects
ADO	: Agriculture Development Officer
AE	: Allocative Efficiency
AHDR	: Assam Human Development Report
AIBP	: Accelerated Irrigation Benefit Programme
ARIASP	: Assam Rural Infrastructure and Agricultural Services Project
ASMIDC	: Assam State Minor Irrigation Development Corporation
BCM	: Billion Cubic Meter
CAGR	: Compound Annual Growth Rate
CBVZ	: Central Brahmaputra Valley Zone
CCA	: Culturable Command Area
C-D	: Cobb-Douglas Production Function
CDB	: Community Development Block
CIA	: Cropping Intensity after Irrigation
CL	: Creamy Layer
COLS	: Corrected Ordinary Least Square
CPR	: Common Pool Resources
DAP	: Di-Ammonium Phosphate
DEA	: Data Envelopment Analysis
DMTM	: Disaster Management and Technology Mission
DoA	: Department of Agriculture
DoI	: Department of Irrigation
DTW	: Deep Tube Well/Deep Tubewell
DW	: Dug Well
EE	: Economic Efficiency
FCI	: Food Corporation of India
FGD	: Focus Group Discussion
FMC	: Field Management Committee
GCA	: Gross Command Area/Gross Cropped Area
GDP	: Gross Domestic Product

GIA	: Gross Irrigated Area
GL	: Groundwater Lift
GoA	: Government of Assam
GoI	: Government of India
GWM	: Groundwater Market
HA	: Hectare
HDI	: Human Development Index
HP	: Horse Power
HSLC	: High School Leaving Certificate
HS	: Higher Secondary
HT	: High Tension
HYV	: High Yielding Variety
IPC	: Irrigation Potential Created
IPU	: Irrigation Potential Utilised
IRRI	: International Rice Research Institute
KCC	: Kisan Credit Card
KG	: Kilogram
KM ²	: Kilometer Square
LLF	: Log Likelihood Function
LLP	: Low Lift Pump
LLRT	: Log-likelihood Ratio Test
MI	: Minor Irrigation
MLE	: Maximum Likelihood Estimates
MM	: Millimeter
MoWR	: Ministry of Water Resources
MOP	: Muriate of Potash
MT	: Metric Ton
NABARD	: National Bank for Agriculture and Rural Development
NCL	: Non-creamy Layer
NDP	: Net Domestic Product
NDDP	: Net District Domestic Product
NGO	: Non-Governmental Organisation

NIA	: Net Irrigated Area
NLCP	: Non-Lapsable Central Pool
NSA	: Net Sworn Area
NSDP	: Net State Domestic Product
NSSO	: National Sample Survey Organisation
OLS	: Ordinary Least Square
PCI	: Per Capita Income
PVC	: Polyvinyl Chloride
RIDF	: Rural Infrastructure Development Fund
SC	: Scheduled Caste
SFA	: Stochastic Frontier Approach
SHG	: Self-help Group
SKY	: Samriddha Krishak Yojana
SL	: Surface Lift
SSIU	: Small Scale Industrial Unit
SSP	: Single Super Phosphate
ST	: Scheduled Tribes
STW	: Shallow Tube Well/Shallow Tubewell
TE	: Technical Efficiency
T-L	: Translog
VLEW	: Village Level Extension Workers
WED	: Water Extracting Devices
WEM	: Water Extracting Mechanism



Abstract

Expansion of groundwater based irrigation technology has facilitated the emergence of institutions like groundwater market or water market in some states of India including Assam which lies in Eastern India with abundant groundwater reserves and heavy monsoon precipitation ensuring easy replenishment. In view of the fact that small and marginal farmers dominate the agricultural scenario of the state with limited capability for capital investment, expansion of groundwater markets is thus, considered as an alternative institution which can ensure equity in access to irrigation across farmers. However, due to the residual nature of the market, the buyers may be subject to inadequate water supply resulting in differences in the attainment of technical efficiency of the farmers under different structures of the market. With this backdrop, the study has been conducted to examine the nature, structure and functioning of groundwater markets in the state; to identify determinants of groundwater markets; to examine the issue of reliability and the factors affecting reliability of the market; and to examine technical efficiency across the farmers under different structures of the market.

Both secondary and primary data are used to carry out the study. Secondary data have been used mainly to examine the status of groundwater based irrigation development in the state. In order to examine the issues of groundwater markets, the study has mainly used primary data collected from 198 respondents from two districts of Assam, viz. Nagaon and Morigaon which constitutes the Central Brahmaputra Valley Zone (CBVZ) of the state. The nature and structure of the market, characteristics of tubewells and underlying production system of the crop undertaken have been examined using simple statistical tools like percentage, ratio, average, etc. The determinants of tubewell ownership, water buying and selling decisions of a farmer and the determinants of reliability of the market have been examined using the logit regression model. The Stochastic Frontier Approach (SFA) is used to estimate technical efficiency scores on a farmer's plot. The variation in the farm specific technical efficiency is obtained by modeling technical inefficiency as a function of some of the farm-specific characteristics.

Groundwater market in the study area is found to be informal. Groundwater has been treated as a *de-facto* open access resource by the owners of tubewells. Six alternative forms of market arrangement for groundwater use have been found. About 5.88 percent of the sample tubewell owners have been found possessing tubewell only for selling groundwater. Thus, on the seller's side, it shows that the market has helped some of the tubewell owners to sell

water not only in excess of their own use on self-operated area but also taking groundwater pumping as an additional source of income. It also suggests that the market is not residual to all buyers. The majority of the buyers are found to be marginal (56.82 percent) and small farmers (41.54 percent). About 65.98 percent of the water sellers belong to the marginal and small farmer categories. The size-wise analysis has shown that when farm size increases, the number of buyer decreases but the reverse is not always true for the sellers. The market is found to be localised in nature due to limited availability of conveyance facilities. Though water transaction has been found to be taking place in both cash and kind, non-cash transaction is found to be dominant. Water transaction is bound by personal relationship (kinship) between buyers and sellers resulting in concession on water charge and differential treatment by some of the sellers. The market is found to be exploitative in nature as some of the buyers are required to render some other services to the sellers against which they are not paid. The market is also found to be interlocked with the existing land tenancy. The prevalent water charge is found to be almost uniform within a village and across villages excepting a few, though there are concessions to buyers who are relatives of the water sellers in a few cases. Though the majority of the tubewells are diesel operated, there is a gradual shift towards electrical pumpsets mainly due to lower operational cost and fluctuating prices of diesel. There are differences in input use, extent of farm mechanisation, number of groundwater applications and yield of the crop between the sellers and buyers.

The results of the logit regression analysis have shown that own farm size, education and age of the head of the household, access to formal sources of credit, availability of off-farm income sources have significant and positive influence on the probability of a farmer's decision to own tubewells. Land fragmentation is found to reduce a farmer's probability of owning a tubewell. The results of the logit analysis for water buying decision of a farmer have shown that own farm size, farmer's access to institutional credit, age, education and better contact with extension agencies reduce probability of water buying decision of a buyer. For a tenant farmer the probability of buying water is higher. Moreover, his probability of buying water increases as distance between his plots and the nearest source of irrigation decreases. The logit estimation of the likelihood of sample farmers' decision to sell groundwater has shown that an owner with an excess capacity of his tubewell and a relatively deeper tubewell has higher probability of selling water. The owner of diesel operated tubewells is more likely to sell water than the owners of electricity operated tubewells and owners of both electricity and diesel operated tubewells. Availability of conveyance facilities is found to increase probability of selling water. The results of the

regression analysis, thus, imply that water selling and buying are the results of the combined effect of a number of socio-economic, farm specific and tubewell-specific factors.

Regarding reliability of the groundwater market, it has been found that the availability of water to the owner-cum-sellers is conditional upon a few limited factors like good condition of the pumpsets/borings, relative scarcity of groundwater due to simultaneous drafting by all the farmers and the inadequate supply of electricity, etc. On the demand side, as high as 62 percent of the buyers have found the market unreliable. Among the reasons cited by the buyers, inability to buy fuel to operate the pumpsets and presence of multiple buyers against a single seller are the two main reasons. The results of the logit model have shown that quantity of groundwater purchase, tenancy, education of the farmer, types of fuel/power used to operate the tubewells are the significant determinants of reliability of the market.

The results of the stochastic translog production function indicate presence of technical inefficiency and a difference of up to 55 percent between the observed and best practice output. Average technical efficiency score on both buyers and sellers' plots are found to be similar but there is further scope for increasing output on buyer's plot. Similarly, the small and marginal plots have recorded higher technical efficiency than the semi-medium and medium plots. The owners of tubewell, who have participated in the market as "self-users+sellers+buyers", are found to have attained higher average technical efficiency score than only "self-users". It indicates that the market has induced enhancement of technical efficiency of the market participants. The availability of off-farm income in the farm household, better contact with the extension services and use of organic manure are the significant factors determining technical efficiency of the sample farms.

Based on the findings, the study concludes that groundwater market in the study area resembles most of the characteristics of water market observed in other Asian countries with a few differences. The study identifies the need of electrification along with regular and adequate electricity supply and promotion of joint ownership of tubewells so that the marginal and small farmers can tap the benefits of groundwater irrigation. With a view to promote efficiency in input use, the study argues for need of training on farming and expansion of government extension services. As the situation of relative scarcity of water has been noticed, the study argues for some sort of regulation for efficient and sustainable use of groundwater.



CHAPTER ONE

INTRODUCTION

1.1 Background of the Study:

Increasing use of groundwater for domestic, industrial and agricultural purposes and the consequent impending water scarcity and groundwater contamination in many parts of the world, have beguiled renewed interests on groundwater management at all levels (local, national and international) of policy deliberation. The built-in perception that “abstraction now, management later” has got radical changes and in almost all cases management has preceded abstraction (Kemper, 2005). The rapid population growth, expansion of water intensive technologies and changes in cropping pattern are some of the factors that have aggravated the problem of water scarcity to a great extent (Saleth, 1994). However, in the face of supply constraints (i.e. sources of usable water on the earth is finite), it is widely recognised that the epicenter of the problem partly lies in the ‘resource system’ itself. Groundwater is a Common Pool Resource¹ (CPR) and shares two key characteristics: subtractability i.e. one person’s use reduces its availability to other users and non-excludability which implies that due to physical nature of the resource it is technically not feasible to exclude potential users from using it (Conroy, 2002; Ostrom, 1990, 2000). The basic CPR problem associated with groundwater use is the appropriation externality which implies that increased withdrawal by one pumper reduces the amount of water that other pumpers can obtain from a given level of investment in pumping inputs resulting in sub-optimal allocation of inputs in the appropriation process (Ostrom, 2000). According to Bruggink (1992), common pool problems develop, when, (a) the pumping drawdown at any particular well lowers the water table and adversely affects the pumping efficiencies for neighbouring wells, (b) decisions on current rate of pumping do not include the effects on future supply, (c) incentives are lowered for conservation and reclamation efforts i.e. when no property rights to un-pumped water are assigned or specified, individual will not be interested to spend on conservation of water because conservation of X acre feet in period t_1 does not guarantee X acre feet of additional water for that individual in period t_2 , (d) the drawdown creates interchange with a surface water source or another underlying formation and (e) the drawdown causes ground subsidence (which may permanently

reduce recharge capacity and pumping efficiency of the aquifer.² Howe (2002) also stated that owing to inappropriate legal and administrative settings, groundwater becomes an open access resources resulting in excessive contemporary and inter-temporal externalities. The common pool resource problem associated with groundwater use becomes more stringent if proper institutions are not designed for governing it. According to Schmid (1972), institutions concern "...sets of ordered relationships among people which define their rights, exposure to the rights of others, privileges and responsibilities". These rights basically property rights, structure the incentives and disincentives between and among individuals in their decisions regarding water use (Ciracy and Wantrup, 1969). Further, Saleth and Diner (2005) has defined water institutions "...as the rules that define action situation, delineate action sets, provide incentives and determine outcome both in individual and collective decisions setting in the context of water development, allocation, use and management. Like all institutions, water institutions are also subjective, path dependent, hierarchical and nested both structurally and spatially and embedded within the cultural, social, economic and political context". The institutional arrangement for allocating groundwater among several competing independent users bears importance because it largely affects efficiency, equity and sustainability of groundwater use.

Thus, in the face of growing water scarcity and various dimensions of groundwater management, there is an urgent need for better institutional arrangement for groundwater use (Howe, 2002). In this regard, Kemper (2005) has pointed out two alternative institutional arrangements: (a) formal and the informal institutional arrangements in the water sector and (b) the institutional arrangement originating in other sectors. Formal institutional arrangements in water sector, according to Kemper (2005) are the constitutions, water laws, subsidiary legislations and administrative rules while customs, generally accepted codes of behavior and social norms are the examples of informal institutional arrangements (Ostrom, 1990). Institutional arrangements made and geared towards other sectors which have bearing on water extraction decisions of users include energy and health policies of a country. While these institutions as pointed out by Kemper (2005) are general in nature, institutions governing water management may be different from one country to another depending on the resource condition, socio-economic condition, climatic conditions, etc. of the country concerned. For example, Saleth (1996) has identified governmental policies (e.g., water pricing

policies and power tariff policy), economic institutions (e.g., rental markets for irrigation assets, groundwater markets and farmers' organisation) and legal institutions (e.g., irrigation acts and water laws) as some of the major institutions governing water resources in India. Saleth (1994) observed that, "...in the face of general failure of state-sponsored initiative the spontaneous emergence and growth of groundwater transfers among farmers observed especially in parts of Gujarat, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Punjab and West Bengal have raised hope of researchers and policy makers in their search for an alternative institutional mechanism for efficient groundwater utilisation and management."

However, of these institutions especially in the face of failure of a centralised administrative control over water, more widely discussed institution for water resource management is the market for groundwater or 'water market' or 'groundwater market'. The terms water market and groundwater market are used interchangeably in the literature as there is no such market for surface water (Saleth, 1996). The basic argument advocating market mechanism for management of water is the belief that market increases economic efficiency by allocating resources to their most valuable use through changes in economic incentives among the users of the resource (Marino and Kemper, 1999; Mohanty and Gupta, 2002). A further argument put forward is that markets are more flexible than administrative allocation mechanism and allow users autonomy in their decisions. For example, when users themselves can decide if they want to buy or sell, those who sell their water do so voluntarily and get a financial compensation (Marino and Kemper, 1999). Marino and Kemper (1999) draw the distinction between a water market and a more administrative approach on three principal grounds: (i) the need for defined transferable water use rights which are regarded as proprietary; (ii) institutions internal to the market, such as information and transaction mechanism to facilitate the transferability of the right and (iii) a mechanism to negate the effects of third party interests or to mitigate impact which might occur because of the transfer of water use rights.

In the literature, there are two lines of definition of water markets. The first one refers to water markets that involve annual or permanent transfer of the water use rights between a willing buyer and a willing seller in exchange for compensation determined by supply and demand, the cost of mobility, the reliability of the supply, and the cost of

mitigating any environmental and third-party effects (Simpson, 1994). Secondly, water markets refer to a localised village level informal arrangements for water transactions whereby owners of Water Extracting Devices (WEDs) (e.g., pumpsets or tubewells) sell water or irrigation services³ to neighbouring farmers at prices mostly determined by the incremental cost of pumping (Shah, 1991, 1993). Water under the second form of market arrangement, may be lifted from open wells or tubewells, deep or shallow tubewells or from canals, tanks, rivers, drains or such other surface sources. Apart from this, another form of interrelated market associated with water defined in the literature is the rental market for pumpsets. Rental market allows farmers to irrigate their farms by renting pumpsets and other lift irrigation arrangements (Saleth and Thangaraj, 1993; Saleth, 1996). Kolavali and Atheeq (1993) termed groundwater markets as markets for 'irrigation services' as groundwater and irrigation assets are interrelated. These two lines of definition of water markets indicate that water markets are of two types: formal and informal. The distinction between formal and informal water markets lies in their legal status. Under the formal water markets, water rights are clearly and universally assigned with legal validity for freely negotiated sale of these rights while in case of informal markets there is neither clear assignment of rights nor legal sanction to trade (Mohanty and Gupta, 2002). As Easter et al. (1998) observe, "...the key difference between the formal and informal water markets is the enforcement of trade. If the enforcement is by the users with no recourse to legal or administrative system, then the market is informal", otherwise the market is formal. Easter et al. (1998) has further added that in formal water market the water sale can be for a specified volume of water or share of water right for a set period of time or sale can be for the transfer of permanent water rights. On the contrary, in informal water markets there is the sale of unmeasured flows of surface water in a canal for a set period of time or from a well based on the number of hours the water is pumped (Easter, 1999). Formal water markets are mostly found in the Western United States, Chile, Australia, Peru, Spain, Mexico, and in some parts of South Africa, North Africa and Brazil (Bjornlund and McKay, 1998 & 2002; Bate, 2002), Georgia (Isley and Middleton, 2003) while informal water markets are pervasive in the irrigated areas of Asian countries: Pakistan, India, Bangladesh, (Pakistan Water and Power Development Authority, 1990; Rinaudo and Stosser, 1997; Meinzen-Dick, 1998; Shah, 1991, 1993; Saleth, 1996, 1998), Indonesia, Jordan (Meinzen-Dick and Mendoza, 1996) and China (Zhang, 2006). However, Thobani (1997) has pointed out widespread existence of informal water

markets in Mexico even before the introduction of formal tradable water rights. World Bank (1999) has pointed to the existence of informal water markets in Mexico, alongside the more recent formal water markets⁴.

Regarding the nature of informal market, Thobani (1997) has observed that in a situation where governments have failed to respond to rapidly changing demands for water, local (spot) water markets have emerged in several water scarce countries or water scarce regions of many countries. Such markets are informal and users contract for water on their own without recourse to any legal provisions. The mode of operation in informal market, as Thobani (1997) has observed, involves selling a specified volume of farmer's surplus groundwater or surface water for a specified period to neighbouring farmers, or several farmers collectively selling some of their water to a nearby town⁵. Zhang (2006) has defined groundwater market as localised, village level arrangements through which owners of tubewells sell pump irrigation services to other farmers of the village (i.e. they sell water to other farmers from their wells for use on crops). However, Pant (1992) has brought out the definition of informal water markets and underlying conditions for existence of the market in a very precise manner. According to Pant (1992), water market or groundwater market is "a market that refers to sale of water versus hire of private pumpsets or boring"⁶. According to him, water markets are likely to exist in a situation where following four conditions are satisfied: (a) the buyers perceive irrigation through purchase of ground water as the most agreeable alternative in comparison to other sources of irrigation; (b) water supplier has pumping capacity in excess of his own requirements and he perceives water sales a profitable proposition; (c) willing buyers are available within the command area of the suppliers' irrigation equipment in case of the pumpsets is fixed (in case of mobile pumpsets, there is no fixed command and there managerial control is more important); and (d) buyers are able physically to gain access to the water.

There has been notable growth of informal groundwater markets in India mainly in agricultural sector along with the spread of groundwater irrigation triggered by the green revolution⁷. Although water trading traced back to the 1920's but a systematic documentation of them began only in the late 1960's (Saleth, 1998). Saleth (1998) also notes that "... although water markets in India are localised, fragmented and vary in terms of maturity, they are an evolving institution with substantial efficiency and

welfare effects”. Narain (1997) in this regards notes, “... the emergence of groundwater markets could perhaps best be viewed as a response to the pattern of development of ground water in the country, which has largely left behind a vast chunk of farmers who are unable to afford water extraction mechanisms.” However, the existence of groundwater markets is not uniform throughout the country. In some states such as Gujarat, Maharashtra, Haryana, Andhra Pradesh, Tamil Nadu, Western Uttar Pradesh, Punjab and West Bengal the presence of such markets is more widespread (Saleth, 1996). Although occurrence of groundwater markets is more widespread in these states, development of the market is more pronounced in Gujarat (Narain, 1997; Dubash, 2000, Mohanty and Gupta, 2002). Water markets in Gujarat have existed for as long 70 to 80 years (Shah, 1991; Narain, 1997). However, compared to these agriculturally developed states, in water abundant states in Eastern India, viz. eastern Uttar Pradesh, Bihar, Orissa, Assam, etc. the presence of such markets is very thin (Shah, 1991; Dutta, 2011, 2012). The differences in the occurrence of groundwater markets are the result of a number of factors: rainfall, groundwater supply, cropping pattern, cost and availability of electricity and development of tubewells under private ownership (Shah, 1993; Saleth, 1994). There is no macro level estimate on the size of groundwater markets in India. However, based on a number of micro studies on water markets, Shah (1993) has estimated that more than 50 percent of the gross area irrigated by private modern WEDs is served by groundwater markets. Saleth (1998), using a methodology based on pumpsets rental data put the figure at 6 million hectares or 15 percent of the total area irrigated by groundwater. Mohanty and Gupta (2002) assuming a contribution of irrigated cultivation to total output at \$230 per hectare/per year, have estimated the total value of output due to water sales to be \$1.38 billion/per year. Further, there is a great degree of variation in the size of groundwater markets among different states. In northern Gujarat nearly 80 percent of the total irrigated acreage is served by water markets (Shah, 1993) while in East and West parts of Uttar Pradesh it is 73 to 79 percent respectively (Pant, 2002). Similarly, 40 to 60 percent of irrigated land is irrigated through water markets in Allahabad district of Uttar Pradesh (Shankar, 1992) followed by 30 percent in Vaigai Basin in Tamil Nadu (Janakarajan, 1993, 1994).

The major issues that have dominated the studies on informal groundwater markets in South Asian context include: equity, reliability of the water markets, efficiency in groundwater use along with the other inputs, impact of the market in the enhancement

of income and sustainability of the groundwater resource. Almost all studies (e.g., Shah, 1988, 1991, 1993, 1999; Pant, 1991, 1992, 2005; Meinzen-Dick, 1995, 1996, 1998; Palmer Zones, 2002; Singh, 2002; Joshi, 2002; Zhang, 2006; Khanna, 2006; Dutta, 2011; Khair et al., 2012, etc.) note the favourable impact of water markets in terms of extension of opportunity to equitable access to groundwater irrigation to the small and marginal farmers and generation of gains for the buyers such as higher and risk-free income realisation and employment through increase in crop yield, cropping intensity, changing cropping pattern in favour of high value crops and use of modern agricultural technologies which are scale free. Since the market is residual in nature (i.e. the water sellers usually sell water after meeting their own requirements), buyers are subject to inadequate water supply when needed. This indicates unreliability of adequate provision of water to the buyers (Meinzen-Dick, 1998). The unreliable nature of the market may also indicate difference in the realisation of technical efficiency between buyers and sellers. Regarding impact of the groundwater markets on attainment of technical efficiency, Manjunatha et al. (2011a, 2011b) have found that the farmers who have participated in the market have achieved higher technical efficiency (TE) scores on their plots than those who have remained outside the market. However, they have noted the differences in the attainment of TE score among owners of tubewells, water buyers and water sellers. Srivastava et al. (2009) in their study on impact of groundwater market on water use efficiency for 100 sample farm households in the Central Plain Zones of Uttar Pradesh have found that both buyers and owners of WEMs are technically inefficient in water-use, as the actual use of irrigation water is found to be much higher than the optimum level. Khanna (2006) has noted the difference in TE scores between owner and buyers where buyers' plots are the least efficient than the plots owned and operated by the owner of tubewells. In addition to this, some studies (Jankarajan, 1993; Shah, 1993; Satyasai et al., 1997) point out the presence of monopoly power enjoyed by the water sellers-cum-big landlords. With the monopoly power, the sellers charge water rates higher than the incremental cost of pumping (e.g., 2.5 to 3 times the marginal cost and 1.25 to 1.8 times of average total cost and thereby appropriate sizeable amount of profits (Shah, 1999)). There is also non-price discrimination whereby sellers refuse to supply waters to the buyers during crucial periods based on various socio-economic factors which are mostly non-market in nature which, in turn, makes the market unreliable for the buyers (Meinzen-Dick, 1998).

Although most of the studies point out that the general mechanism underpinning operation of the market is similar, there are significant differences in the mode of operation and nature and types of contracts with their serious implications on functioning of the market. Based on different commercial and non-commercial aspects of water markets, Saleth (1998) notes that water markets in India display a wide variation in terms of organisational features and behavioural pattern⁸. However, proponents of groundwater markets have concurred that these differences are obvious as groundwater markets are village level localised institutions (Pant 1991; Shah 1993; Joshi 2002, Zhang 2006) and highly dependent upon agro-climatic conditions, status of agricultural development, farming practices or technology, levels of economic development, socio-economic conditions of the farmers. There are also differences in the issues of groundwater markets in water abundant regions compared to the water scarce regions. In the presence of such differences, Dubash (2000) notes that instead of looking at how the markets work or do not work, it is important to look at how and why they work differently in different locations, under different social and hydrological circumstances and with what effects. In this respect, Palanisami and Easter (1991) have observed that even in the presence of monopoly position on the part of the seller-cum-well owners, in the water abundant region the best strategy is to encourage or legalise trading and increase competition either through community or private well development. Shah (1991) observed that water abundant region (Eastern India in his example) offers a major opportunity where development of water markets can transform the stagnant agriculture to a booming economy. The question in abundant region, as Shah has pointed out, is how to speed up the development of water markets and saturate the available potential. In the same context Saleth (1994) also observed that the issue in groundwater development in Eastern part of India which is marked by abundant groundwater supply is different from the water scarce southern region. Major issue in water abundant region, according to him, is the groundwater promotion rather than regulation and one has to focus on correction of institutional and technical bottlenecks for more development of groundwater for the promotion of agriculture.

Besides these aspects, the unresolved question overlying the recent debate on groundwater markets is the apprehension that informal water markets may lead to over exploitation of the groundwater resources with serious ramifications on inter-temporal externalities in the form of declining water tables, higher pumping costs, lower well

yield or even abandonment of wells especially in the water scarce regions⁹ (Chambers et al., 1989; Moench, 1992; Shah, 1993; Janakarajan, 1993; Saleth, 1994, 1996; Narain, 1997; Meinzen Dick, 1998; Singh, 2002; Mazumdar and Mondal, 2008). Since individual farmers are more concerned with their private gains and costs and may completely ignore social cost of overexploitation of groundwater resources, growth of groundwater markets may aggravate aquifer depletion¹⁰ (Saleth, 1998). However, one implication of such deliberation is the property rights issue of groundwater in India. The ownership of groundwater in India is attached to land and the landowners have the right to extract groundwater beyond any limit until it is available. Under such a situation pricing of water failing to reflect scarcity value of water may lead to overexploitation. This ultimately may result in allocative inefficiency, inequity in resource use and ecological un-sustainability (Saleth, 1996; Narain, 1997). Although the problems may not seem to be so intensive in the water abundant regions, the possibility that unregulated groundwater abstraction can eventually lead to local problems of groundwater overexploitation can't be ruled out (Moench, 2001).

Thus, it is clear that as a response to development of groundwater based irrigation technology, there is emergence of institutions like groundwater market or water market in some states of India. The size and growth of the market and its inherent issues depend on the status of agricultural development, agro-climatic conditions and level of groundwater development. In contrast to other parts of India, Assam in Eastern India has abundant groundwater reserves with heavy monsoon precipitation facilitating easy replenishment. Regarding groundwater availability in the state, the Central Groundwater Board (CGWB) has estimated the net availability of annual replenishable groundwater at 24.89 bcm, out of which 22 percent are drafted for all purposes (industrial, domestic and agriculture) (Govt. of India, 2006). Of the total development, as much as 89.15 percent is used for agricultural purpose and the rest (10.84 percent) is used for both domestic and industrial purposes.

According to the data available (Govt. of Assam, 2013b), out of the total geographical area of 78.44 lakh hectares, the Gross Cropped Area (GCA) of Assam is 41.05 lakh hectares. Against this, the ultimate Gross Irrigation Potential (annually irrigable area) has been estimated at 27 lakh hectares, which constitutes 65.80 percent of the GCA. The irrigation development in the state has been undertaken under two broad schemes,

viz. Major/Medium irrigation and Minor Irrigation. Based on technology, irrigation schemes are also categorised as Surface Flow, Surface Lift (for Major/Medium and Minor) and Groundwater Lift (for Minor). Out of the Gross Cropped Area (GCA) of 41.05 lakh hectares of the state, the State Irrigation Department created irrigation potential of 7.97 lakh hectares (19.41 percent) up to 2010-11 of which 2.44 lakh hectares (30.61 percent) through Major and Medium Irrigation schemes and the rest 5.53 lakh hectares (69.39 percent) under the Minor Irrigation schemes. However, against creation of such irrigation potential under the government schemes by the State Irrigation Department, as high as 83.71 percent of total irrigation potential created till 2010-2011 is found to have remained unutilised (Govt. of Assam, 2012b). One interesting fact relating to irrigation development in the state is the rapid growth of groundwater based minor irrigation scheme in the late nineties of the previous century. For example, the Compound Annual Growth rates (CAGRs) of total minor irrigation structures in the state was 11.40 percent during 1986-87 to 1993-94, which increased to 16.08 percent during 1993-94 to 2000-2001 while the same for India was 6.99 percent during 1993-94 to 2000-01 (MoWR, 2001, 2005). Among the groundwater structures, Shallow Tubewells (STWs) have recorded phenomenal growth outstripping surface irrigation schemes (surface flow and surface lift) in the state. Compared to surface flow and surface lift, STWs constituted about 68.36 percent of the groundwater structures in 1986-87 which marginally increased to about 69.13 percent in 2000-01 and further to 87.29 percent in 2000-2001. Against this, as per data of the 1st, 2nd and 3rd Minor Irrigation Censuses (Govt. of India, 1993, 2001, 2005)¹¹ in 1986-87, almost 8 percent of the groundwater structures were surface flow. It declined to 5.99 percent in 1993-94, and further to 2.72 percent in 2000-01. Similarly, in 1986-87, while 21.37 percent of the groundwater structures were surface lift, this declined to 23.26 percent in 1993-94, and further to 9.17 percent in 2000-01. Shallow tubewells, thus, are now the most important and fastest growing sources of irrigation in Assam.

One of the striking features of shallow tubewell technology based irrigation development in the state is that these tubewells are installed under private ownership and usually owned by a single/individual farmer. As per the Minor Irrigation Census 2000-01 of Government of India, in Assam about 98 percent of the total STWs has been under the individual ownership. Along with the government supported development of STWs, there has been unprecedented development of STWs at the

private initiative of the farmers themselves (Dutta, 2011). The expansion of STWs based irrigation schemes has also facilitated the farmers especially in the flood prone low lying districts of the state, to shift towards cultivation of *rabi* crops to avoid crop losses during flood period. For example, as per Economic Survey, Assam, 2011-12, the area under summer rice (which predominantly uses STWs) has increased by 10 percent during 2006-07 to 2007-2008. STW based irrigation thus, attracted huge response from the farmers motivating them to procure tubewells privately. Most of the owners of the Water Extracting Mechanism (WEM) with excess capacity of their tubewells engage in water transaction with the neighbouring farmers who do not own WEM (on their own) for market and non-market reasons (Dutta, 2011, 2012). This has resulted in the emergence of groundwater markets in the state.

1.2 Statement of the Problem:

The average size of operational holding in the state is 1.10 hectare only (Agriculture Census, 2010-11, Govt. of Assam, 2013a). Out of the total farm households, more than 83 percent are small and marginal farmers with the size of their operational holding less than 2 hectares (Govt. of Assam, 2012a). In view of the fact that small and marginal farmers dominate the agricultural scenario of the state with limited capability for capital investment, the emergence of groundwater market in the state is considered as an alternative institution which ensures equity in access to irrigation across farmers. With the increased access, it is also expected that the underutilised pumpsets or underutilised created irrigation potential will be better utilised facilitating small and marginal farmers' access to irrigation irrespective of their size of land holding. This, in turn, will enhance income of the owner-cum-sellers and that of buyers through enhancement in production and productivity of the crop undertaken with assured irrigation. However, due to residual nature of the market, there may be a situation where the sellers may refuse to supply or sell water to the buyers during crucial periods of crop growth making groundwater markets highly uncertain and unreliable for the buyers. The inadequate supply of irrigation might have an adverse impact on yield of the crop especially on buyers' plots. Further, in a situation of limited number of sellers, despite availability of water, the market may be more monopolistic having its adverse effects in terms of high water charge. This might have inequity effects upon the buyers who are basically the small and the marginal farmers. Some other factors, that have been

identified in earlier studies on water markets in different countries, viz. Bangladesh (Palmar-Jones, 2002), India (Kajisa, 2005), such as uncertainty and risk involved in contractual arrangement, types of water contract, forms of tenancy, information and incentives, asymmetric bargaining power and availability of institutional credit may also have their impact on the nature and functioning of the market. Circumstances under which a farmer becomes water buyer or water seller might also be different depending on different socio-economic conditions due to regional and localised nature of the market discussed above. Due to unreliable nature of the market there might have differences in the attainment of technical efficiency among different categories of groundwater users in groundwater markets (Khanna, 2006; Manjunatha et al., 2011a, 2011b) Besides, since the issue of property right is intertwined with the appropriate management of groundwater, while looking at the functioning of the water market, it is also necessary to examine the present property right regime over the use of groundwater in the state. Since, most of the issues of groundwater markets are region specific, depending on different agro-climatic and hydrological conditions (particularly in terms of water resources) along with different socio-economic conditions, the structure and functioning of the groundwater markets in the state may also exhibit different characteristics. While a number of important studies on various dimensions of agriculture of Assam have become available by now, studies on groundwater markets, except Dutta (2012) is hardly available. The present study has been induced by the necessity to fill this gap. It is in this context, the present study is undertaken to examine the nature, structure and various issues of the market.

1.3 Objectives:

The study has been taken up with the following specific objectives.

1. To study the nature, structure and functioning of prevailing groundwater markets in Assam.
2. To identify determinants of tubewell ownership, buying and selling decisions of a farmer.
3. To examine the issue of reliability of water markets, determinants of reliability and their relative significance.

4. To examine the technical efficiency on farmers' plots by their status as groundwater users.

1.4 Hypotheses:

The following hypotheses have been pursued in the study.

H₁: Emergence of groundwater market is influenced by own farm size of farmers.

H₂: Groundwater market ensures reliability of water supply.

H₃: Groundwater market enhances technical efficiency of farms.

1.5 Data and Methodology:

The present study has been based on both primary and secondary data. Secondary data pertaining to the status of agriculture in general and irrigation development in particular in the state have been collected from the publications of various organisations, viz. Directorate of Economics and Statistics, Government of Assam; Department of Agriculture, Department of Irrigation and Department of Panchayat & Rural Development, Government of Assam; Central Ground Water Board, Ministry of Water, Government of India; Economic Survey of the Government of India and the Government of Assam; Reports of Center for Monitoring Indian Economy, published documents of the Planning Commission of India, etc. Since National Bank for Agriculture and Rural Development (NABARD) has also been working to create irrigation potential in the state of Assam, reports of the bank have also been consulted for the study.

In order to achieve its primary objectives, the study has mainly used primary data collected from 198 respondents from two districts of Assam, viz. Nagaon and Morigaon which constitutes the Central Brahmaputra Valley Zone (CBVZ) of the state. These two districts have been purposively selected as the presence of groundwater markets is prevalent in some pockets of the districts especially in the cultivation of summer rice (summer rice is locally known as *boro* rice). Sample households who have participated in the ground water market have been randomly selected. A specially structured and pre-tested questionnaire has been administered in the field in order to collect data on

various aspects of groundwater markets for the agricultural year 2011-12. The interview schedule is attached as an appendix (Appendix-4.1).

The data generated from the field survey has been analysed using appropriate statistical tools. The nature, structure and functioning of groundwater markets, general characteristics of the tubewells and general characteristics of the underlying production system of the crop undertaken (summer rice) have been discussed using simple statistical tools like percentage, ratio, average, etc. The determinants of the groundwater market, more specifically the determinants of tubewell ownership, water buying and selling decisions of a farmer have been examined using the logit regression model. Similarly, the issue of reliability of the market and its determinants with their relative significance has also been identified and examined using logit regression analysis. The technical efficiency scores of the farmer's plots under different structures of the market have been estimated applying the Stochastic Frontier Approach (SFA). A single step approach has been followed to obtain the estimates of the translog production function (as translog production function has been found to be suitable than the Cobb-Douglas production function) and the inefficiency model. The detailed methodology has been spelled out in the respective chapters.

1.6 Layout of the dissertation:

The dissertation is comprised of nine chapters including the present one.

The second chapter is a review of available literature on various theoretical issues of groundwater as common pool resource and groundwater markets. The findings of some of the empirical works on water markets found relevant in the context of the present study, has also been summarised in the chapter.

The third chapter depicts the present status of the agricultural economy and the status of groundwater based irrigation development in Assam.

The fourth chapter deals with the background of field study area, sample, broad profile of the sample and a preliminary analysis of field level inputs.

The core of the dissertation begins with the fifth chapter which deals with the nature, structure and functioning of the groundwater markets, the general characteristics of the tubewells and the characteristics of underlying production system.

The sixth chapter deals with the determinants of groundwater markets, more specifically, the determinants of tubewell ownership, buying and selling decisions of groundwater of a farmer.

In chapter seven, the issue of reliability of groundwater markets in ensuring adequate supply of water to the farmers in general and specially to buyers has been examined.

In chapter eight, technical efficiency scores of farms under different structures of groundwater markets have been estimated and examined.

The concluding chapter of the dissertation presents a recapitulation of the major findings, conclusions emerging from the study, a discussion of policy implications and limitations of the study.

Notes:

1. Common Pool Resources (CPRs) share two key characteristics, namely: *Non-excludability*, i.e. it is difficult to physically exclude the potential users from using the resources; and *Rivalry* or their consumption is subtractable i.e. increased consumption by one agent implies less is available for others (Ostrom and Ostrom, 1977; Ostrom et al., 1994, Bromley, 1992, Baland and Plateau, 1992; Conroy, 2002). However, there is a great deal of controversy between the term common property and common pool. When most of the times, the terms are used interchangeably, scholars have clearly distinguished common property from common pool (Ostrom, 2000). The term common property is used to imply a property right regime where the members of a clearly demarcated group have a legal right to exclude nonmembers of that group from using the resource (Bromley, 1991a, 1992b, cited in Ostrom, 2000). Thus, it has no reference to the resource system. There can be common property regime governing common pool resource (in our case groundwater) over and above private property, state property and open access regime. According to Ciracy Wantrup and Bishop (1975) and Vaidyanathan (1999), groundwater is neither a true open access resource because ability to extract groundwater is limited by neither well ownership, nor a common property because it lacks an identifiable group of users to have co-equal rights. In our study we will use the term Common Pool Resource (CPR) to refer to the resource system only.

2. In similar way, Blomquist (2002) notes, “groundwater is literally a common pool. Exclusion of multiple pumpers is difficult and costly (unless the basin is so small that an individual can control access to it). Consumption is rival. As water withdrawals from a basin exceed the amount replenished (due to any combination of more pumpers, greater withdrawals by each or declining replenishment) pumper visit appropriation externalities each other. Underground water levels within the basin decline, lengthening pumping lifts (the distance water must be drawn to the surface). Longer pumping lifts impose increased costs on pumpers. If basin water levels decline far enough, wells go dry and must either be replaced or deepened at even more costs to the pumpers”. (Blomquist, 2002, pp. 283)
3. There was a long debate on the terms water markets or market for irrigation services. Since in the water market water is not sold *per se* but farmers sell water from their own Water Extraction Mechanism (WEM), it is often argued that it is a market for irrigation service (Palmer-Jones, 2002). However, as Shah and Ballabh (1999) notes “many researchers have contested the use of the term “water market” for such transaction because, in principle, the water they pump is not their private property and what well owner sell is merely the services of their pumpsets. It is argued therefore, that these are best referred to as pump rental markets. Technically this seems right. However, the term water market persists in scholarly literature as also in farmers’ usage. One reason is the simplicity of the phrase ‘water market’; but probably a more correct reason is that the water they pump is theirs, and others in the village including buyers do not have any serious objection as long as their right to extract water in future is not encouraged” (Shah and Ballabh, 1999; p. A-189).
4. Cited in Kemper, K. E. (2005), “Rethinking Groundwater Management”, in Figueres. C. et al. (Eds.) *Rethinking Water Management: Innovative Approaches to Contemporary Issues*, Earthscan Publication Ltd. London
5. Although Matinee have not cited any evidence of farmers selling water from their collective source, Moench (1998) observed that in a situation where municipality supply of water is limited or poor, people adjacent to the city sell groundwater to the city dwellers. In Tamil Nadu, groundwater in areas adjacent to Madras is pumped and sold at a rate of roughly \$1/m³. Further markets for water for domestic needs have also emerged in recent year in several rural and peri-urban areas of Rajasthan (Shah, 1993; P.45)
6. Adapted from Viswa Ballabh and Tushar Shah (1989), *Groundwater Markets: A Review of Issues Evidence and Politics*, paper presented in the workshop on Efficiency and Equity in Ground Water Use and Management, Institute of Rural Management, Anand, January 30 - February 1, 1989

7. "The purchase of water for non irrigation uses have been reported in some places, e.g., urban domestic users purchasing water in Tamil Nadu was observed by Palanasami (1994) and Janakarajan (1994)" cited in Mohanty and Gupta (2002).
8. Saleth (1998) notes ".....those in northern Gujarat operate almost like agribusiness with cash-based transactions complete with cash receipts and purchase records. In contrast, water markets in parts of Andhra Pradesh, Tamil Nadu, and southern Gujarat show shades of the feudal character involving 'water rent' and the provision for unpaid labour services. In between these two extreme fall those in the relatively water abundant Indo-Gangetic and deltaic regions that display a rather muted form of commercial character".
9. Harmful effects of over-exploitation of groundwater in different states of the country have been recorded as follows: water logging and salinity in Punjab, Haryana and Western Rajasthan; fluoride contamination in North Gujarat and Southern Rajasthan and ingress of saline sea water into the aquifers in states like Gujarat and Maharashtra (Singh and Singh, 2003).
10. Saleth (1998) notes that "... while the depletive potential of water markets is a forgotten aspect in most initial studies, a few studies do provide evidence that water trading can lead to groundwater depletion. In northern Gujarat which has more intense water marketing, the groundwater table declined about 1.22 m during 1984-88. Notably, the Mehsana and Sabarkantha districts in this region witnessed a 3m decline during the same period (Phadtare, 1988). Similarly, in Vaigai basin, Tamil Nadu, it is observed that, in the aftermath of intense water marketing, the proportion of wells with a depth of over 30 m has increased from 9 to 29 percent, suggesting a clear link between water trade and secular decline in water table (see Janakarajan, 1994)."
11. The fourth Minor Irrigation Census was conducted in the year 2006-07 but the data has not been officially released.



CHAPTER TWO

REVIEW OF LITERATURE

Review of literature assumes immense significance for any scientific investigation. Keeping the broad understanding of informal water markets or groundwater markets in Asian countries as an evolving institution for groundwater use in view, a review of related research studies compiled from both published and unpublished sources has been made in this section. However, before getting on to the investigation into the issues of water markets, a brisk review of studies that have identified common pool problems of groundwater use, property right issue of groundwater use and institutional approach for better management of the resource, has been made. Thus, the whole section of review of literature has been arranged under two broad sections. First section deals with studies which have identified groundwater as Common Pool Resource (CPR), common property problem of groundwater use, institutional response to groundwater management and emergence of groundwater markets as an institution that has facilitated access to groundwater across farmers. In the second section, studies which have examined the nature, structure and functioning of groundwater markets are reviewed. Studies that examined determinants of groundwater market, issue of reliability and water use efficiency of farms in groundwater market are also reviewed under four sub-sections in section two.

2.1 Groundwater as Common Pool Resources and Common Property Problem of Groundwater use: Property Rights Issue in Groundwater Management

Bruggink (1992) clearly brought out that groundwater suffers from common property problems because it is located under or below numerous, independently owned plots of private land. A landowner when pumps water, he begins to obtain economic value of groundwater. Since water is fugitive property resource, more the owner pump the greater the amount he receives at any time. Thus, given the location, well depth, pipe-diameter and pumping rates of the wells, production decision of a well owner affects hydrological characteristics of the basin and common property problems develop when, (a) the pumping drawdown at any particular well lowers the water table and adversely affects the pumping efficiencies for neighbouring wells, (b) decisions on current rate of

pumping do not include the effects on future supply, (c) incentives are lowered for conservation and reclamation efforts. When no property rights to un-pumped water are assigned or specified, individual will not be interested to spend on conservation of water because conservation of X acre feet in period 1 does not guarantee x acre feet of additional water for that individual in period 2, (d) the drawdown creates interchange with a surface water source or another underlying formation and (e) drawdown cause ground subsidence (which will permanently reduce recharge capacity and pumping efficiency of the aquifer. Bruggink further noted that the problem with groundwater supply was a problem mainly arising out of the current system of incomplete property rights. He observed that development of water resources requires certainty of ownership and flexibility in their use and state laws that clearly delineate the property rights associated with groundwater ownership and use. Bruggink also advocated a new system of well-defined, exclusive and freely transferable property rights under private property regime that will provide greater incentives for the water resource development. Under the privatised system, he believed, individuals or firms holding water rights would be free to use the annual water flow, sell it on the open market or accumulate it for future transaction whichever is most profitable to the holder.

Blomquist (2002) notes that groundwater is literally a common pool resource as exclusion of multiple pumpers is difficult and costly (unless the basin is so small that an individual can control access to it) and consumption is rival. He explains that as water withdrawals from a basin exceed the amount replenished (due to any combination of more pumpers, greater withdrawals by each or declining replenishment) pumper visit appropriation externalities each other. As a result of this, longer pumping lifts impose increased costs on pumpers. In a situation when basin water levels decline abruptly, wells go dry. This requires the wells either be replaced or deepened at even more costs to the pumpers.

Sengupta (1993 and 2000) in a study on groundwater management concluded that management of water is a common property management problem. He pointed out that common property problem arises because many farmers have to share water distributed at each outlet including groundwater aquifer which is shared by many. He suggested that common property problems can only be avoided if co-users come to cooperate.

Carruthers and Clark (1981) explored that under unregulated management, where non-renewing of groundwater is held in common ownerships, it is utilised by independent agents. As the individual users' property right to future use of the pool is indefinite, as other pumpers may utilise the water in the meantime. In such instances, the self-interest of the individual user may lead to socially non-optimal pumping regimes.

Young and Haveman (2006) argued that allocation of water among different uses is an economic problem and therefore, policies and institutions for its management should be designed to achieve economically efficient and equitable allocation. They concluded that a system of rights must be well-defined, enforced and transferable and must confront users with the full cost of their actions. They thus, advocated an institutional arrangement in the form of market for rights that readily reflect changing demands and result in better management of the resource.

Smith (1988) observed the role of clear and precise state law in respect of water rights in the absence of which the depletion may take place in an enormous way. According to him "the state law must define the degree of exclusivity of water rights, protect those rights against impairment and specify the terms under which water rights may be transferred."

According to Ruth and Meinzen-Dick (2000) there is legal pluralism in Indian water rights systems. In the presence of legal pluralism, they argued that "...understanding water rights needs to start from the local perspectives of those who use water, their daily experiences, the meaning through which they conceive of water rights and the options they have available for acquiring water and defending their access to this vital resources". According to Ruth and Meinzen-Dick, one of the most important directions for improving allocative efficiency is the recognition and capacity enhancement of user self-governance of water as common property resource. Although around the world, reforms in irrigation institutions have already taken significant steps to incorporate farmers' participation and devolve management responsibility to water users, but water rights need to be more clearly defined and negotiated.

Dhawan (1974) observed the likely impact of groundwater overexploitation or aquifer depletion associated with growth of tubewells especially the private tubewells. He referred to occurrence of such problems in states such as Punjab, Gujarat, Western UP

and Tamil Nadu. In order to arrest groundwater overexploitation, he favoured imposition of certain state intervention in the exploitation of groundwater in terms of both the number of tubewells and their annual withdrawal of water.

Narain (1997) noted that identifying property right structure for water, examining alternative institutional structures for decentralisation, overcoming institutional bottlenecks in the development of groundwater, etc. are some of the emerging policy and institutional challenges in the fields of groundwater management. According to Narain although the benefits of water markets in terms of increase in efficiency and equity are best known, they are little difficult to quantify. But it is also recognised that in the absence of a well-defined property right structure in water, the development of ground water markets could stimulate aquifer depletion.

Saleth (1994) argued that the present water crisis is the result of failure of our current water related policies and the instruments and institutions through which they are implemented. He argued for the establishment of water right system to correct this policy failure in managing water. Water right system, according to him bear institutional significance in the sense that it is one of those rare policy instruments that can help achieving three critical goals of sustainable development: ecological security, economic efficiency and social equity. Referring to the spontaneous evolution of water market institutions among the users and growth of user-based organisation, he hoped potentiality of water users to adapt to an institution based on water right system.

Saleth (1996) observed that groundwater market, which is still in the process of evolution as a rural institution, have substantial efficacy and equity implications for the utilisation of both groundwater and energy resources as well as irrigation assets like wells/pumpsets. However, he noted that unregulated spread of water markets may exacerbate groundwater depletion. The depletive effects of groundwater markets, according to him occur essentially due to the absence of a clearly defined property right system to specify some upper limit (i.e. water quota) for both individual and collective groundwater withdrawals. Since social costs of water extraction does not enter in to one's or users' extraction decisions leading to inter temporal allocative inefficiency, the solution for the problem lies in the establishment of water rights. He advocated for the establishment of water rights in such a manner that not only defines individual and collective water withdrawals through some sort of water quotas but also designs

suitable organizational forms for enforcement and monitoring of the established rights systems.

Schmid (1972) favoured a number of institutions that concern "...sets of ordered relationships among people which define their rights, exposure to the rights of others, privileges and responsibilities". These rights basically the property rights- structure the incentives and disincentives between and among individuals in their decisions regarding water use (Ciracy and Wantrup, 1969).

World Bank (1993) advocated for pricing policy as an appropriate measure for groundwater management. The basic principle underpinning pricing policies states that by raising the user price of water to reflect its true scarcity or opportunity cost (that is, the price the marginal user is willing to pay), authorities hope to induce users to conserve water, making it possible to divert supplies to higher value uses.

Glasbergen (1995) emphasised that along with assigning property rights for groundwater ownership and use there is also need for demand management. He noted that despite adoption of state rules in Netherlands, there is depletion of groundwater because of inadequate demand management. According to him, the system also needs to provide for measures aimed at managing the demand for the resource and measures aimed at preservation of the resource. Management of the demand for the resource requires incentives that reduce water use.

Hariprasad and Sengupta (2008) exploring the nature and causes of extraction and depletion of groundwater argued for the need for policy intervention by the states keeping in view the future value of groundwater. He advocated for decentralised approach as the best alternative compared to the centralized approach.

Asserting that economic prosperity and property rights are inextricably linked, O'Discill and Joskins (2003) emphasised the importance of having well-defined and strongly protected property right regime. He advocated private property right, which gives individuals the exclusive right to use their resources as they see fit and allows the property users to take full account of all the benefits and costs resulting in economic efficiency.

Vaidyanathan (1999) argued that rights to ground water should be that of use and not of ownership. If ownership has to be decided, it should be with the state, but with use rights going to the community. This community can be a village or number of villages situated in a hydrological zone. In addition, the regulatory rights should be transferred to the community. The state should facilitate the functioning of the community and the efforts to harness and conserve water resources by providing technical and financial inputs for monitoring groundwater and the status of water balance.

Meinzen-Dick and Mendoza (1996) reviewed three alternative water allocation mechanisms: centralised administrative control, user managed allocation and market allocation drawn from the Indian and international experiences. They concluded that no single type of allocation is best for all contexts. The strategic role of centralised administrative control is essential particularly in circumstances that involve large scale investments especially to minimise negative effects associated with water extraction, which include: water logging and salinisation, falling groundwater tables, destruction of habitat and downstream pollution due to agricultural runoff, sewage contamination or industrial effluent. Public water allocation, according to them has advantage over state control in gathering information about localised variations in supply and demand and deems more appropriate where there are relatively few decisions affecting large numbers of people. However, according to them market allocation has strong advantages in providing incentives for users to seek the highest value application for scarce water resources. Yet, for effective operation of water markets, well defined, quantifiable and transferable property rights must exist which can be established with state assistance.

Moench (1998) in his paper reviewed the water right system in India and observed the failure of centralised schemes regulating groundwater overexploitation. Because groundwater is an open access resource in the current legal system in India, defined by the system that groundwater extraction rights is chattel to land, a land owner considers groundwater beneath his land as his own property and extract as much water as he wishes. In order to correct the situation he argued for restructuring government approach that would create a balance of power in water use decisions between private (either individual or groups) right holders and common rights. In this connection he also felt need of local user organization in management decision especially in

restructuring groundwater recharge. In order to ensure social legitimacy in these two systems, he argued for creation of independent water courts.

Ballabh (2001) analysed the inter-sectoral water use competition and the consequent potential conflicts. He concluded that in the absence of well-defined property rights regimes in river or stream flow surface water, groundwater resources are *de-facto* open access resource regime and as a result the riparian doctrine does not encourage socially optimal use of water.

Howe (2002) stated that owing to inappropriate legal and administrative settings, groundwater becomes an open access resources resulting in excessive contemporary and inter-temporal externalities. He argued that though several instruments like limits in well spacing and capacities, pumping taxes and tradable pumping permits had been used, for sustainable management of the resource, rates of economic and demographic development have to be planned.

Considering over exploitation of ground water beyond the sustainable limit in most parts of the state of Rajasthan, Rathore (2002) suggested three complementary options to deal with the problem: treating water as an economic good, legal and regulating provision and as community resource. Rathore pointed out that pricing as a market instrument for controlling demand for water in India has been a failure as this is mostly used as part of larger agricultural policy instead of considering it as part of policy designed for management of water as an economic resource. Groundwater being a common pool resources, according to Rathore, the basic issue involved in groundwater management is that of right which requires a clear definition. The present legal status that defines ownership over groundwater is chattel to land under the Easement Act of 1882, has to be revamped so as to avoid open access problem of groundwater use.

Reddy (2003) mentioned five types of externalities associated with groundwater overexploitation: vertical, horizontal, stock, cost and legislative externalities. He advocated integrated approach for groundwater development in conjunction with surface water. Further, economic pricing of electricity with monitoring, proper institutional arrangements, de-linking of water rights from land rights, users' participation (through village level institutions such as *Pani Panchayat*) are also essential to ameliorate this externalities.

Kumar (2003) argued for proper understanding of several aspects of groundwater management including the role and likely impact of pricing of power and electricity subsidy to agriculture, increasing level of cross subsidisation, differential impact of power pricing and supply policies on different sections of the society, over estimation of power consumption in agriculture participatory approach in order to ensure efficiency, equity and sustainability.

Kumar et al. (2003) pointed out harmful effects of groundwater over-exploitation which can be listed as salinity in Punjab, Haryana and Western Rajasthan; fluoride contamination in North Gujarat and Southern Rajasthan and ingress of Saline water in to the aquifers in states like Gujarat and Maharashtra. He specifically mentioned that rent seeking motive of the private pumpers induced by the provision of free electricity is the main reason for overexploitation of groundwater. They advocated initiating a number of reforms to check such problems. These reforms include: reduction of subsidy towards electricity for agricultural purposes, crop diversification, educating farmers for adopting water saving farming practices and water harvesting technologies, rationalising irrigation charges to charges on volumetric basis and bringing users in to decisions making and management. Further, he pointed out decay of common property water institutions like village tanks, ponds, etc. as major factor for emergence of groundwater crises in India.

Joshi (2005) enlisted three serious consequences of ground water depletion and the rise in water table which include increase in the cost of irrigation, decline in productivity and increase in income disparities among the users. There he felt urgent and concerted measures for effective management of ground water. These include: technological options, policy options institutional arrangement and legislative measures. Among these measures Joshi emphasised on collective action for effective management of ground water which is to be well designed relating to decision making arrangements and patterns of interactions. Joshi also noted down need for revamping traditional property rights highly dominated by private property rights.

Shah (2008) advocated for the adoption of both demand and supply side management simultaneously for management of ground water along with participatory arrangement (e.g., Hivre Bazaar and Ralegaon Siddi, Tarun Bharat Sanghs, The Andhra Pradesh Farmer's). He concluded that since India's ground water crisis is a part and parcel of

agricultural crisis and state subsidized. The former cannot be solved without correcting agricultural crisis, the ground water crisis can hardly be resolved. The solution although lies in removal of power subsidy the same cannot be realised given the political economy involved with agriculture. In such situation Shah felt need for legislative measures for watershed development so as to recharge aquifers.

Thus, in the face of growing water scarcity and in the wake of centralised failure, the recognition that groundwater as common pool resource problem has promoted an urgent need for better institutional arrangement for groundwater management. Kemper (2005) has pointed out two alternative institutional arrangements: (a) formal and the informal institutional arrangements in the water sector and (b) the institutional arrangement originating in other sectors. Formal institutional arrangements in water sector, according to Kemper (2005) are the constitutions, water laws, subsidiary legislations and administrative rules while customs, generally accepted codes of behavior and social norms are the examples of informal institutional arrangements (Ostrom, 1990). Institutional arrangements made and geared towards other sectors which have bearing on water extraction decisions of users include energy and health policies of a country. While these institutions as pointed out by Kemper (2005) are general in nature, institutions governing water management may be different from one country to another depending on the resource condition, socio-economic condition, and climatic conditions, etc. of the country concerned. For example, Saleth (1996) has identified governmental policies (e.g., water pricing policies and power tariff policy), economic institutions (e.g., rental markets for irrigation assets, groundwater markets¹ and farmers' organisation) and legal institutions (e.g., irrigation acts and water laws) as some of the major institutions governing water resources in India. However, of these institutions especially in the face of failure of centralised administrative control over water, more widely discussed institution governing use of water at large, is the market for groundwater or 'water market' or 'groundwater market'

2.2 Issues of Groundwater Markets:

2.2.1 Nature, Structure and Functioning of the Groundwater Market:

As has been mentioned in the introductory section, groundwater markets in agriculture sector of South Asian countries have evolved as a spontaneously-developed institution for water management and enjoyed significance as a means of increasing access to and

use of groundwater for irrigation. Although modern water trading is a long standing practice in South Asia and traced back to 1920's in India, importance of informal water markets has been recently recognised and empirically examined (Meinzen-Dick, 1998; Saleth, 1998). A great deal of studies have been done on water markets, especially in the later part of 1980's. Most of the studies on informal groundwater markets are based upon field studies conducted in India, Bangladesh, Pakistan, Nepal and recently a few in China.

All these studies, reviewed in the subsequent paragraphs, deal with the details of groundwater markets mainly pertaining to size, forms of water transaction, water charges, characteristics of buyers and sellers and their impact on water transaction, impact of water markets on production and income and the issues equity, efficiency and reliability of water markets.

Pant (1992) in his study to see the pattern and pace of private groundwater development including the ground water markets within and outside the commands of the World Bank assisted public tubewells in two districts, viz. Faizabad and Bahraich of Eastern UP found widespread occurrences of water trading among the farmers. He observed that existence of large quantity of unexploited ground water in the region and large number of small and marginal farmers and landless labourers inhabiting the region led to emergence of water markets. In this seminal work, Pant defined groundwater market as "a market that refers to sale of water versus hire of private pumpsets and or boring". According to Pant water markets are likely to exist in a situation where following four conditions are satisfied: (a) the buyers perceive irrigation through purchase of ground water as the most agreeable alternative in comparison to other sources of irrigation, (b) water supplier has pumping capacity in excess of his own requirements and he perceives water sales a profitable proposition, (c) willing buyers are available within the command area of the supplier's irrigation equipment in case of the pumpsets is fixed. In case of mobile pumpsets, there is no fixed command area and their managerial control is more important and (d) buyers are able physically to gain access to the water. In the study he found as high as 91 percent of owners of pumps in Faizabad districts sold water to others whereas in Ghurupur and Maghgawa villages all owners of pumpsets sold water. In Bairah district 76 percent pump owners sold water to the others. The variations in sale of water pertained to differences in landholdings and

types of power used. Regarding water charges Pant found that charges were mainly in cash not in kind and were uniform for all categories of farmers. The rate was determined on hourly basis and there were also partial and seasonal payments. In a situation when a seller was also a buyer in different locations, there were some mutual understanding that resulted in low water rates. Taking all these factors into account, the owner to electric pumpsets charged ₹ 3 to ₹ 5 per hour from buyers. In case of diesel pumpsets regardless of the horse power of the pumpsets, the water rate varied between ₹ 12 to ₹ 14 per hour. One interesting feature they brought in to light was the fact that the pumpsets owners with electric pump preferred to sell water to the buyers on fixed payment basis which was found to be about ₹ 313 per hectare for the whole seasons. Similar to other studies (Ballabh and Shah, 1989), he concluded that groundwater market is directly proportional to the small size of landholdings; smaller the size of land holdings, higher the number of small and marginal farmers higher is the chance of existence of groundwater market.

Pant in this study also summarised major findings of his earlier studies on water markets conducted in UP. In his 1981's study he found larger incidence of purchase and sale of water and observed that in Eastern UP (Deoria district) 14 percent of the sample farmers owned pumpsets and the remaining 86 percent purchased water. In central (Barabanki) and western (Meerut) UP about 35 percent of farmers owned pumpsets and 65 percent purchased water. In his 1983's study he found sale of large proportion of water extracted from group tubewells owned and operated by small and marginal farmers. The groups sold water to outsiders sometimes more than the water sold to the members (particularly in Deoria district of UP and Vaishali districts of Bihar). In Deoria district, 25 tubewells under group ownership irrigated a total of 308.8 ha of land (12.4 hectare per tubewell) of which 41 percent consisted of members' land the rest 59 percent was non-members' land who purchased water. Similarly, in Vashali district 48 percent of the total land was irrigated through the purchase of water from 25 group tubewells. In his 1991 study in eastern India states of Orissa, West Bengal, Assam (however, he had not given any information relating to functioning of the market) and Bihar found existence of water markets in a pervasive manner where mostly rich farmers with own tubewell sold water to small and marginal farmers. As an exception, he noted that small farmers belonging to ST category (who owned tubewells from the state) sold water even to the affluent farmers. According to him purchase of

water in these states was on hourly basis. This rate varied from state to state and situation to situation and ranged from ₹ 8/- to ₹ 25/- per hour for a pumpset with the average capacity of 5 H. P.

Shah (1991) defined water market as a localised village level informal arrangement through which owners of water extraction mechanisms sell irrigation service or water to other members of the community. Water under such market arrangement, according to Shah, may be lifted from open wells or tubewells, deep or shallow tubewells or from canals, tanks, rivers, drains or such other surface sources. Shah noted down three types of contract that dominated water transactions in the early phase of its development in India. These are: (a) labour contract in which the buyer will provide labour and draft power to the seller in return of water, (b) crop-sharing contract in which the seller provides only water while the buyer provides land, labour, manure, and other inputs and both share the crop and (c) crop and input sharing contract in which the buyers provide land and labour, the sellers provide water and other inputs. In the second form of contract the sellers' share in output ranged from 33 percent to 55 percent and in the third contract between 50 to 66 percent. Shah found presence of natural oligopoly in water markets where the sellers enjoy more control than the buyers and thus can charge different prices. According to Shah, emergence of monopoly power among the sellers is inevitable due to capital intensity of modern water extraction mechanism, spacing norms in installing the water extraction mechanism and incremental cost of pumping due to energy pricing policy. He suggested for adoption of flat rate power tariff and quality and timely supply of electricity to ameliorate monopoly power. Apart from these, he suggested for provision of capital subsidy to the poor to install tubewell in eastern region of India, viz. Orissa, West Bengal and Bihar to expedite development of the water market and thereby increase competition and efficiency of the markets. In the face of depletion of aquifer, he suggested for conjunctive use of groundwater and surface water in order to achieve water use equilibrium.

Kolavali (1989) observed that markets for groundwater emerged where well owners had surplus water and there was high demand for irrigation water. This increased the return on groundwater investments and induced investment in mechanisms to reduce conveyance losses. According to him, private sales of water overcame the problem of indivisibility of groundwater investments and provided non-well owners access to

groundwater. Although well owners are in a potential monopoly position, pricing is influenced by the fact that water has to be sold in the vicinity of the well. Water charges are determined by costs, monopoly rents and local tradition. Water markets according to Kolavali, increased agricultural production as the buyers enjoyed more control over irrigation.

Narain (1997) observed that ground water markets in India emerged in response to the pattern of development of ground water in the country, which largely left behind a vast chunk of farmers who were unable to afford water extraction mechanisms. He noted down role of groundwater market in India's ground water economy on three counts: groundwater markets enable marginal and small farmers to enjoy the benefits of ground water lifts and thereby help enhance their incomes, help their owners to improve the economic viability of their lifts and thereby enhance their incomes, help the society by minimizing investments in ground water lifts.

Raju and Rao (1991) in their study conducted in three districts of North Coastal Andhra Pradesh, viz. Srikakulam, Visakhapatnam and East Godavari; observed that all the sellers of water were medium farmers while all the buyers were small farmers. The prices were charged based on the number of hours the pumpsets was put to use and the rates varied from ₹ 4/hour in Visakhapatnam to ₹ 7/hour to ₹ 8/hour in East Godavari and ₹ 5/hour in Srikakulam. The prices were uniform in all the markets and there was no seasonal variation. Although spread of water markets resulted in employment generation in all sample villages but employment generation was relatively more pronounced in Srikakulam district. They argued for the development of water market under group and common ownership of private tubewells since the farmers deducing benefits from the water market were the small and marginal farmers.

Shah (1988) pointed out four beneficial effects of water markets: (i) higher and more risk free income flows from farming for non-WEM owners who with a water market have access to modern farming technologies, (ii) appreciation of market value of non-WEM owner's land, (iii) opportunities offered by water market to small holder WEM owners to increase WEM utilisation beyond what their own land would permit and thereby to spread its overhead on a larger command area; and (iv) improved wages, more and seasonally balanced employment opportunities for the landless. Pointing out the limitation of public control of groundwater resource, he emphasised on managing

the same through private irrigation development. However, in the face of aquifer depletion, he argued for rationalising the structure of private returns in irrigation which could be based on the following premises: “(a) the rate of increase in the population of private WEMs in a region can be regulated by a licensing policy supported by an annual license fee, (b) the rate of pumping by a cluster of WEMs in a region can be regulated by influencing the incremental cost of pumping mainly through the pricing of electric power, (c) a structure of incentives can be created to influence farmer preferences towards ground versus canal water, and (d) it might even be feasible to create a structure of incentives to induce private pumpers to use their spare pumping capacity as a pure drainage device to pump ground-water into the canals.” Shah pointed out that the objectives of regulatory mechanism should be different depending on the water profiles of a region. While the underlying objective is to maximize equity in access to the resource where it is plentiful, the main aim of such mechanism is to minimise adverse ecological effects in areas under stress with minimum damage to the interests of the resource-poor. His one of the commendable policy suggestions, i.e. the electricity pricing, according to him would not be more effective in the water stress region. The most equitable long-term solution in these areas, of course, would be to increase aquifer recharge rate and surface water resources through long distance water transport.

Saleth (1991) based on the analysis using data from the Fertiliser Demand Survey conducted by the National Council for Applied Economic Research (NCAER) during 1976-77, found that in the Indo-Gangetic states (especially Bihar, Haryana, Punjab, Uttar Pradesh and West Bengal) climatic failure particularly the untimely or delayed rainfall significantly influenced the groundwater buying decision of farmers. Role of other factors such as farm size, soil fertility and percentage of farm area under canal irrigation was relatively less and differed from one state to other. He further noted that groundwater markets had powerful welfare effects in terms of both increasing and stabilising small farmers’ income through reducing probability of crop failure with access to purchased water.

Asopa and Dholokia (1983) found wide spread operation of water markets in Gujarat and reported 50-66 percent increase in buyers’ crop output as result of the spread of the markets.

Prasad (1991) in his study on water markets from a village of the Musahari block of the Muzzafar district of Bihar found that water market was less beneficial in terms of both equity in access to irrigation and increase in agricultural production especially for the small and marginal farmers. This was mainly due to the fact that the market was more controlled by the large landholdings class and there were large variations in water charges depending on the control of the water sellers. Prasad argued for uniform water charges to make water markets work for the small farmers.

Narayana (1991) in a study on irrigation development in Kerala found that there had been wide spread growth of irrigation under private sector as a result of government's effort to promote groundwater irrigation. He observed that the government's financial subsidy towards promotion of tubewell irrigation led to concentration of pumpsets in the hands of farmers with large size of land holdings. This inequality in the distribution of firms and the destruction of traditional irrigation structure repelled the small farmers without own pumpsets to purchase water.

Agarwal et al. (1991) studied the structure and operation of water markets in Dabra block of Bilaspur district and found that water markets providing assured irrigation facility resulted in more diversification of crop. Agarwal et al. observed more participation of small and marginal farmers in the market who purchased water for cultivation of summer groundnut at remunerative prices.

Palanisami and Easter (1991) observed that issues of water markets in water abundant countries are different from that of water markets present in water scarce region. They observed that even in the presence of monopoly power or position on the part of the seller-cum-well owner in the water scarce region the best strategy is to encourage or legalise trading and increase competition either through community or private well development.

In his study, Shanker (1992) observed widespread presence of water markets in Bahadurpur Block of Allahabad district of in eastern UP. He found that as large as 57 percent farmers with land holding less than 1 hectare irrigated their land through purchased water followed by small farmers (25 percent), semi-medium and medium farmers 15 and 3 percent respectively. Farmers in the size category 4-10 hectares of landholding were the largest sellers of water. Regarding benefits of the market

expansion, he noted that water markets resulted in almost equal benefits to both the owner and non-owner in terms of yield per hectare of the major crop such as wheat. The yield rate of wheat for the tubewell owners was 24.6 quintals/ha while it was 23 quintals/ha for the purchasers. Income from the sale of water per tubewell was estimated at ₹ 2, 154 and covered two thirds of the cost of running tubewell when operating expenses were considered. Taking interest on fixed capital, depreciation and imputed value of family labour in to account, it however, accounted for 31 percent of the total cost. Regarding sources of finance, he noted that institutional sources of finance were very less. Sale and mortgage of land (18 percent of total finance) were important sources of finance.

Nandakini (1992) noted down the benefits of water markets in terms of extension of more areas under cultivation making agriculture more viable, availability of water to the small and marginal farmers and creation of employment opportunities in agriculture. Nandakini felt importance of water market even in the presence of monopoly because according to him without the knowledge on the poverty and income level of the farmers before the emergence of water markets, impact of monopoly in terms of equity cannot be assessed. The two more concerns (i.e. one how to restrict private monopoly over scarce water resources and second, how to promote conservation of water) although deems important for water scarce region, they are not as serious in water abundant region. Nandakini emphasised more conjunctive use of water in canal command areas for enhancing efficiency and equity along with the focus on property rights. Finally, Nandakini discerned significance of studying both land and water market in an integrated manner as former can influence functioning of the later to a greater extent. However, he did not point out the issues that should be considered in studying this.

Palmer-Jones (1993) inveighed against two dominant propositions of groundwater markets that (a) there are natural oligopoly in groundwater markets and (b) the public policy such as flat electricity charge rate in order to make the market more competitive; on the grounds that both were not constructed on correct theoretical framework and no empirical evidence supported it. According to Palmer –Jones, study of water market independent of labour and rural credit markets is incomplete as many transactions in water markets depend upon the functioning of rural informal credit and the agricultural

insurance markets. The terms of transaction in water markets (such as per hour and per acre payments) itself may beset with incentive problems and may not work properly if there is no established link with the credit and insurance markets. Palmer-Jones also identified one contestable area of groundwater market where groundwater is abundant. In this area, according to him, markets will be relatively more competitive once technology becomes well known and easily available and there is good supporting infrastructure with developed agricultural output market. One interesting observation of Palmer-Jones is the fact that understanding of South Asian water markets is incomplete if spatial characteristics are not considered. Because this market can vary greatly both regionally (defined by hydro-geological, agro-climatic and socio-political characteristics) and locally.

Janakarajan (1993, 1994) based on a field study in the Vaigai Basin of Tamil Nadu (including Maduari, Quaid E-Millath, Pasupom, Thever Thirumagan and Ramanthpuram districts), observed functioning of water markets even in the situation of receding groundwater table. However, there were some changes in the characteristics of the water markets which he listed as increasing use of conveyance arrangement in the form of piped-lines instead of earthen channels, joint pumping, increase in electricity consumption and increase in monopoly in the hands of well-endowed farmers. He observed large variations in prices for water within the villages. The water charges were made in terms of both cash and kind. In Vaigai basin water rates ranged from ₹ 4/hour (for electric pump) to ₹12/hour (diesel pumpsets). In Sirunavalapatu village, the water charge was made in terms of produce which was one-third of the total produce. Janakarajan observed unequal access to resources, poor bargaining capacity and dependent status of water purchasers compared to the water sellers. The water purchasers were also conceived to render certain services which include: vigilance in the water sellers' pump-house, irrigating water sellers' land first, cleaning and desilting the field channels that convey water from the well to the water seller's plots, assisting in lifting the motor and pump from the well in the event of repairs to the pumpsets and protecting the sellers' crops from grazing cattle. He found the market relatively less beneficial for the small and marginal farmers. He advocated state interventions to restrict exploitative motive of the water sellers in the form of "...denying institutional finance to those who dig new wells in a prohibited area or to

those who do not maintain the spacing between wells imposed by a state agency or denying electricity connections to those who violate government regulations.”

Shah (1993) in his pioneering work on water markets highlighted the potential of water markets benefiting the resource poor-small and marginal farmers through assured and reliable irrigation, increase in agricultural production and income of the farmers. Shah argued that the equity and efficiency of the development of water markets could be enhanced by shifting to flat rate of electricity. Under flat electricity charges, according to him, marginal cost of extraction or pumping is close to zero which results in lower prices for water. This, in turn, reduces monopoly power because Shah believed that water prices in a region “are explained not by the aquifer conditions but by the degrees of water seller’s monopoly and by incremental costs”. Shah in the same work also opined that the pace of growth of water market depends upon availability of water supply.

Fujita and Hossain (1995) studied the role of groundwater markets in irrigation development and its impact on the rural income distribution in Barind tract in the North West villages of Bangladesh. They found that the groundwater market was highly monopolistic in terms of water charges. The water charge demanded by the tubewell owners in the study village was, on an average, as high as 2.59 times the variable cost for TW operation. The average w/ac in the study villages found in the range between 1.13 to 6.8, which is higher than the w/ac reported by other studies in Bangladesh (where it was found in the range of 1.16 to 2.53). However, comparing the rate of profit (69 percent, measured in terms of Internal Rate of Return) with the long term rate of interest in the informal financial markets (38 to 61 percent under the *khaikhalashi* system of land tenancy) they found profits accruing to the TW owners were more or less economically reasonable. Groundwater markets viewed from this argument was rather efficient and competitive. Further, Fujita and Hossain reported that, water sales took place in three systems of payment; i.e. crop sharing system, fixed cash payment (per acre) system and a mixed system of crop sharing and cash payment. The average payment under the said systems were: under the crop sharing buyers paid 33 to 40 percent of the total produce (in monetary terms 3000 to 3500 Bangladeshi taka per acre), under the fixed cash payment system the rate ranged from Rs.2100 to 2400 taka per acre and under the mixed system a portion, usually, 300 taka per acre was paid in

cash in advance and the rest was paid as share of the crop which was usually 33 percent of the total produce. Regarding the impact of water markets on factor shares in rice production they observed that the factor share of land decreased substantially from about 50 percent to 22 percent while the capital increased from less than 10 percent to more than 20 percent though labour share did not experience any major shift/change. They argued that groundwater markets had positive impact on the small farmers because they also enjoyed the benefits of increase in the capital share which lowered income disparity. The exploration and interlinking of this relation has been identified as a fertile area for future research.

Strosser and Meinzen-Dick (1994) noted the importance of groundwater markets in Pakistan in increasing access to groundwater resources especially among the small and fragmented holdings but found it underdeveloped compared to India's groundwater market. The markets did not spread because tubewell owners-cum-sellers gave more priority to providing groundwater to their own land instead of selling it to the farmers adjacent to their land. However, wherever existed, the tubewells owners exercised a greater control over the pumped water. As result the water purchasers were unable to achieve as much productivity gains as deduced by the sellers.

Agarwal (1996) in her study examined the relationship between risk sharing and functioning of water markets and found timeliness or reliability of irrigation services in sharecropping contracts for moisture-sensitive crops in Gujarat.

Satyasai et al. (1997) based on a sample study of 90 irrigators in Hindpur Taluk of Anantapur district of Andhra Pradesh observed that groundwater markets increased access of small farmers to water. However, they found presence of monopoly in the functioning of the groundwater markets and high water charges compared to the cost of irrigation. They estimated that water were sold for ₹ 7.70/per hour under hourly arrangement and for ₹ 50/per hour under crop sharing arrangement which were 14 and 91 times higher than the operation and maintenance cost of ₹ 0.55/per hour accordingly.

Thobani (1997) observed that recent approaches for water management, focused on voluntary mechanisms to conserve and reallocate it among competing uses rather, are of three types: pricing policies, informal water markets and water markets. He observed

that in a situation where governments failed to respond to rapidly changing demands for water, local (spot) water markets emerged in several water scarce countries or regions of many countries. Such markets especially found in South Asian agricultural practices are informal, where users contract for water on their own without recourse to any legal provisions and involve selling a specified volume of farmer's surplus groundwater or surface water for a specified period to neighbouring farmers, or several farmers collectively selling some their water to a nearby town. Thobani pointed out three serious fallouts of informal water markets: first, wealthier farmers with deep tubewells may charge neighbouring smaller farmers a high monopoly price for water resulting in lower output of crop and widening of income inequality (as observed in south Asia), secondly, since the transactions are illegal, the buyers lack the security to an enforceable contract and informal markets does not provide any incentives to the public authority to invest on new infrastructure development as it does not add anything to government's coffers.

Kumar et al. (2004) based on a study in Banaskantha district of North Gujarat found that groundwater irrigation strengthened the financial health of well owners, water buyers and agri-labourers. According to them, though impact of groundwater irrigation on production is positive, depletion of groundwater leads to increase in the cost of production due to which economic returns from farming is reduced.

Shah and Ballabh (1997) in his study in the six villages of Muzaffarpur district of Bihar (viz. Binpur, Panpur, Morsandi, Barji, Anana Court and Nariyar) found widespread prevalence of the water markets with nearly half of the irrigated land served by the water markets. Despite abundance of groundwater in the state, the pricing of pump irrigation service was strongly influenced by the monopoly power enjoyed by the WEM owners who charged a water price varying between ₹ 20 -30 per hour. The water charges exceeded their incremental pumping costs by 2.5 to 3 times and average total costs by a factor of 1.25 to 1.8 times. They also found strong indication of change in irrigation costs which increased mainly in response to increase in price of diesel. Relating to the gains accrued by the buyers they estimated from a Focus Group Discussion (FGD) that in Panpur village one Rupee spent on purchasing groundwater had a marginal product as high as 5.5 – 9.1 kg of maize, 5.1 – 12.3 kg of *rabi* wheat, 4.3 – 10 kg of paddy and up to 43 kg of potato. Since groundwater overdraft is not an

issue in the state, they advocated development of groundwater markets (through subsidy in electricity) as a powerful anti-poverty and agricultural development strategy.

Meinzen-Dick (1998) in her study on water market in Punjab Province of Pakistan observed that groundwater markets helped increase in productivity and income of the farmers which resulted from increase in input use, increase in crop yields and switches to more profitable but water sensitive crops. Studies, cited by Meinzen-Dick, such as Freeman et al. (1978) and WAPDA (1980) also noted the positive impact of water markets on purchasers using public canal and public tubewell supplies in Pakistan. However, they found the gains accrued to the small farmers were less than the tubewells owners. Regarding water charges, he found that the flat charge per hour of pumping (ranging from \$0.57 to \$3.27 per hour) and buyer's fuel arrangement (whereby, the buyer supplies the diesel and motor oil for the pump and pays an additional fee (\$0.13 to \$0.24 per hour to the well owner to cover the wear and tear on the engine) were the two most common ways of water transaction.

Easter (1999) advocated water markets in the sense that it can provide appropriate economic incentives to improve the efficiency of water use and encourage the reallocation of water to higher-valued uses without encountering the traditional opposition of existing water users. Drawn from the south Asian experiences in water market he concluded that water markets according to him can increase access to irrigation especially for small farmers who do not own tubewells and can not afford to invest in a well without a market for their required water. Spread of water markets has increased farmers' income and production. According to him that some of the contracts for water are quite similar to the contracts for land. Contracts for water include crop sharing, crop and input sharing and labour arrangements. He further noted that types of contract affect buyers' decisions to go for alternative sellers. According to him when transaction is a contract in kind, especially one based on crop sharing or input sharing, the buyer is tied to the seller for at least one season, if not longer. Similarly if buyers contract to pay for the water with the labour they may find it difficult to find suppliers until they have fulfilled the contract.

In an important study Dubash (2002) has made a comparative analysis of two groundwater dependent villages in North Gujarat. The major finding of his study is that the water contract between buyers and sellers is complex and governed by social

process. He has used three indicators to assess the nature of exchange, viz. “market architecture”-the density of tubewells, “market thickness”- density of exchange and terms of payments; and the “terms of exchange” and found significant variation in groundwater exchange. The mode of transaction of water is found to be cash price per hour or fixed share per acre or output sharing. There is differential treatment to tenant buyers and they are mostly required to make payment in terms of fixed share per acre. Dubash has found the market competitive in the sense that the price charge is uniform across buyers.

Mohanty and Gupta (2002) studied functioning of water markets in different parts of the world and found that formal and developed water markets helped in water conservation and efficient use of water. With formal water markets, according to them, farmers want to use water saving technologies in production and produce highly valued crops that are less water intensive. Though Indian water markets are mainly informal, localized and primitive; the formal markets have positive impact on water use. Based on the study, they advocated the establishment of formal water markets which will expand the scope of water trading and make inter-sectoral water transfers possible.

Singh (2002) observed that water market in India is an informal institution as it has not been legally recognized. The farming community fixes the terms and conditions itself that is generally followed by all the water users (buyers and sellers). However, operation rules differ from one place to another making water markets location-specific. Singh highlighted some important issues in groundwater markets which included: in the water scarce regions water sellers enjoy a monopsony position and act in a concerted manner, profit maximization is the sole motive of water sellers and they appropriate a large amount of profit when water transaction takes place in terms of kind such a sharing of output and the existing institutional set-up both formal and informal are not adequate to arrest aquifer depletion. The absence of clear-defined property rights over common pool resource, according to him is the major cause of aquifer depletion.

Singh and Singh (2003) in their study on groundwater market based on sample of 180 farms from Meerut district of Western Uttar Pradesh (undivided) found a large proportion of sample farm households (82 percent) entering in water markets either fully or partly. The small farms household dominating the agrarian structure and

uneven distribution of land among different categories of farms have resulted the buyers to have an inverse relationship with the farm size and sellers to have a direct relationship with the farm size. Their estimate on the extent of market shows that without the market for groundwater over one fourth of land would have remained non-irrigated especially on marginal and small farms. This indicates that the groundwater market is beneficial for the small and marginal farmers. Small and marginal farms had been found mostly engaged in buying activities than the selling activities. In terms of use of input (fertiliser and irrigation) and yield realised buyers recorded lower score than the Water Extraction Mechanism (WEM) owners. Though accessibility to groundwater across the farm sizes almost had been found same for all categories of groundwater users, there was inequity in the realisation of gains in winter season crops among them. Regarding reliability of groundwater market, the study concluded that the groundwater market was less reliable for buyers compared to the owner-cum-sellers. Further, electric operated WEMs had been found less reliable than the diesel operated WEMs as the former were subject to higher breakdown and erratic electricity supply. Though the study emphasised on quality power supply so as to maximize the benefits of groundwater market, it advocated need for a rational electricity tariff to discourage over-exploitation of groundwater.

Jacoby et al. (2004) in their empirical study on water market in the Punjab Province of Pakistan have examined the extent of price discrimination exercised by the water sellers. They have found that high investment costs and credit constraints in installing a tubewell and conveyance losses have given some monopoly power to the water sellers. The link between water market and land tenancy has been identified by them. They also have found that water sellers favoured tenant buyers. Based on field evidences, they strongly argued that there is monopoly in the operation of groundwater market in Pakistan.

Kajisa and Sakurai (2005) examined the issues of efficiency and equity in groundwater markets with special attention to output sharing contract and to the bargaining relationships between sellers and the buyers using house level data from six villages in two adjacent districts (viz. Hoshangabad and Narsingpur) in Madhya Pradesh, India. They found that groundwater markets helped the farms achieving efficiency in terms of optimal input intensities which was achieved through effective monitoring and contract

adherence mechanisms embedded in long-term and intensive personal relationships between buyers and sellers. On equity aspect, they found that while output sharing buyers paid higher water prices, the rate of premium was merely 5 percentage points higher than the informal interest rate if they would had to carry the same under other types of groundwater contracts. However, they concluded that if imperfection in credit and contingent markets is taken in to account, informal groundwater markets would work fairly well in agrarian communities provided there are sufficient numbers of potential sellers.

The study conducted by Pant (2004) has recorded the evolution of water markets in eastern and western Uttar Pradesh and found that there is gradual shift towards electricity operated tubewells in the surveyed village of Tameigarhi. The demand for water in the study area has increased the amount of investment on private ownership of tubewells among the farmers. Further he noted that land fragmentation has been a major stumbling block in speedy coverage of land area under tubewell based irrigation.

Pant (2005) pointed out the spread and importance of water markets in Uttar Pradesh in making water available to small and marginal farmers and efficient allocation or use of groundwater. He noted down that in 1981 when 28 percent of the households in western UP and 16 percent households in eastern UP irrigated their farm land through water market or purchased water, in 2002 the same increased to 79 percent in the west and 73 percent in the east. Although he did not record the importance of water markets in 1981 survey, he observed the importance of the same in 1992 survey where he found small farmers with land holding 0.4 ha as the biggest beneficiaries. He recorded that of the total farmers of this category; more than 60 percent of them irrigated their crop by water purchased from owners of private Water Extracting Devices (WEDs) while as low as 7 percent of them irrigated their land from the public tube wells. Regarding sources of power, he observed that in the west about 50 percent sold water through electric tubewells, 44 percent through diesel pumps and the remaining 5 percent sold water through their own bore wells. On the pattern of water charges he recorded spatial variations and variation relating to sources of power. For instance, in the eastern part bore well was hired at ₹ 3.4/per hour while in the western part the average charge was Rs. 5.4/hour. Charges for electricity varied from ₹12.1/ per hour in the West to ₹ 13.0/hour in the East. In case of pumpsets using diesel the water rates were a bit high,

while the average charges for diesel operated tubewells were ₹ 45.1/per hour in the West, the same was ₹ 44.8/per hour. He also found that water markets resulted in economic and efficient use of electricity irrespective of rates: unit or flat. Kishore and Verma (2003) also pointed out positive impact of water markets irrespective of rate of unit or flat.

Hussain et al. (2005) in their study on water markets in Pakistan found prevalence of informal water markets for canal water and groundwater. In view of limited availability of canal water, groundwater trading is found to be prominent. The survey results reveal that 6 to 7 percent of the sampled farmers are engaged in water trade at the head and 20 percent sell water at the tail of the distributaries. The canal water rate varies from \$2 to \$3 per hour mostly to neighbouring farmers. Almost all tubewell owners have found to selling water at a rate ranging between \$1 and \$3 per hour. The distance over which water can be transported has stood as a limitation to water market sales. They have found that almost all buyers of water have found the market unreliable for them.

Zhang (2006) based on a survey of 24 randomly sampled villages and 50 randomly sampled tubewells in two provinces (Hebei and Henan Province) in 2001 and a field survey of 68 randomly sampled villages in 4 provinces (Hebei, Henan, Shanxi, and Shaanxi) of northern China in 2004, found emergence and rapid development of groundwater markets in northern China. The markets were informal and localized and developed in a way similar to water markets found in South Asia. Zhang observed price discrimination by the sellers and transaction was mainly based on cash payment. Regarding genesis of the market, their econometric results showed that the privatization of tubewells was one of the most important driving factors that encouraged the development of groundwater markets along with increasing water and land scarcity.

Singh (2007) in his attempt to understand the operations of groundwater markets in fragile conditions in the State of Rajasthan and who are the losers and gainers in the game of water markets in the long-run, found that water markets mitigated inequalities in accessibility to groundwater resource in the short-run. But, faster and excessive use of groundwater may increase inequity among the farming community in the long-run. In water-scarce regions, water markets function on the principles of profit maximization. The different strategies are adopted to make groundwater available for sale. The water markets operate under monopsonic conditions. The terms and

conditions of groundwater markets, i.e. kind or cash, vary differently across the regions. The study has suggested that water rights should be redefined and nationalization of groundwater resource is the only alternative for its sustainable management. To restrict the overexploitation of aquifers, water trading should be allowed in a limited manner. Programmes for recharging aquifer should be initiated on a large scale. A community-based action is required for the efficient use of water resources in water-scarce conditions through effective institutional arrangement.

Mondal and Majumdar (2008) recorded beneficial impact of water markets in terms of productivity enhancement, increase in cropping intensity and income or value per output of the participants comparing with the non-participants in Nadia and Birbhum districts of West Bengal. Salient findings of their study include: (a) maximum benefits are derived by the marginal farmers who own the maximum amount of surplus water for sale; (b) existing water market is mainly dependent upon paddy, the main food crop for the people of WB; (c) water markets has resulted in near optimal distribution of groundwater. Regarding net income from sale of irrigation water, they found that in the developed districts the per hectare earning from the sale of irrigation was the highest from summer paddy (₹ 1, 158.92) followed by Wheat (₹ 6, 16.12), Mustard (₹ 410.61), Vegetable (₹ 358.09) and *Kharif* Paddy (₹ 151.95). On the contrary, sellers of irrigation in the less developed districts earned ₹ 500 per hectare from vegetable followed by potato (₹ 405.39), Wheat (₹ 398.85), Summer Paddy (₹ 300), Mustard (₹ 146.18) and *Kharif* Paddy (₹ 119.85). Relating to water rate structure they observed that average rate per hour for all classes of farmers was ₹ 25 in *Kharif* season, ₹ 32.50 in summer season and ₹ 30 during perennial orchard. Along with this beneficial impact of groundwater markets they also noted adverse impact of it in terms of aquifer depletion.

Aideshu (2008) in his study undertaken in the states of Andhra Pradesh and Orissa, found that the spread of water market was not successful in enhancing utilisation rate of groundwater due to exorbitant price charged by the owners of water extracting devices besides influence of other factors such as the failure of tanks, decreased potential of groundwater, untimely and inadequate rainfall, untimely power supply, etc. Drawn from total sample farmers of 240 from each state, they observed that in Srikalashasthi Mandal of Chittoor district of Andhrapradesh on an average the water sellers charged ₹ 16.16/per hour for paddy, while it was ₹ 19.21/per hour in Madgula Mandal of

Visakhapatnam District. On average water charges in Ganjan and Rayganda districts of Orissa were ₹ 29.25 per hour during the *Kharif* season and ₹ 30.82 per hour during *Rabi* season.

Jha and Sinha (2008) in their study in Patna and Jamui districts of Bihar and Giridh and Pakur districts of Jharkahand observed positive impact of water markets on the improvement of yield per hectare of the major crops such as wheat, paddy, maize, masoor and potato in both the states. However, farmers with WEDs enjoyed higher gains in productivity enhancement compared to the farmers without their own WEDs. The cost of irrigation for all farmers without OWEDs was many times higher than the cost of irrigation for the farmers with OWEDs. Regarding water charge rate it was recorded that transaction took place on an hourly basis in both the states. In Bihar, while on average water was sold for ₹ 47.63/hour in *Kharif* season it was sold for ₹ 42.92/hour and ₹ 47.68/hour in summer season. In Jharkhand, on average, water was sold at ₹ 45.20/hour for all seasons, in *Kharif* season it was sold for ₹ 40.95/hour and in *rabi* season it was sold at ₹ 48.55/hour. They also observed unreliability of the market as the market failed to supply water to the buyers during their needs.

Saikia (2008) studied the impact of STWs in three districts in Assam (Viz. Sonitpur, Nagaon and Jorhat) in terms of yield rate, adoption of new technologies, changes in cropping pattern especially towards high valued crops, cropping intensity comparing these with the non-tubewells owners. Saikia found that yield rate of irrigated holding over un-irrigated holding of the beneficiary farms was higher than the non-irrigated land by 15.58 percent, The yield difference between beneficiaries and non-beneficiaries was found to be 27.68 percent and the aggregate yield variations of paddy in un-irrigated holdings in beneficiary farms were found to be higher by 10.98 percent over the non-beneficiary farms. He noted a marked difference in cropping intensity. The overall cropping intensity in the irrigated holding was found to be 182 percent against 143 percent in un-irrigated holdings. The study also indicated that with assured irrigation facility the farmers shifted from traditional varieties to High Yielding Varieties (HYV). He also reported sharing of STW irrigation with the non-owners Field Management Committee (FMC) member. But no mention was made about the term and conditions under which water was transacted. In order to enhance the performance of STWs-based irrigation schemes, he felt need for better water management, timely

supply of credit and inputs, effective agricultural support services, conjunctive use of water and co-ordination of all the departments or agencies.

Verma and Bhatia (2008) in an attempt to study functioning of water markets and their impact on production in Joypur and Jalore districts in Rajasthan found a wide range of variations in the functioning of water markets in different situations. While in scarce regions water market was of monopolistic type and sellers maximized profits by charging higher prices from the buyers, in water abundant region water market was more competitive and sellers tended to maximize profits by maximizing the sale of water at lower prices. Regarding mode of operation of the market they observed that water was traded both in cash and the kind (share crop basis) in both the districts. Similarly, regarding impact of water markets they did not find any significant differences between well owners and non-well owners in respect of cropping pattern, labour use and crop yield. They observed deepening of wells in the studied districts on an average by 10 to 12 feet every year. Pointing to enormous institutional support in the form of subsidized inputs and credit which resulted in excessive groundwater development leading to depletion of the aquifer, they argued for a separate groundwater policy so as to control such unrestricted extraction and involvement of people in the conservation program.

Mukherji (2008) in an attempt to estimate the spread of water markets at a macro-level, using data from three rounds of National Sample Survey Organisation (NSSO) (31st, 48th and 54th) for two periods 1976-77 and 1997-98 found that the area irrigated through pump irrigation services has increased from 1 million hectares in 1976-1977 to an estimated 20 million hectares in 1997-98. In the analysis Mukherji discarded one of the popular myth in the literature on water market that the market is underdeveloped in Eastern India. At the same time, the study had found no evidence in support of the fact that water market has declined in southern India due to depletion of groundwater. Mukherji rather has shown that there is no absolute decline in the size of water market in southern region.

In his study, Dutta (2012) found presence of water market in the studied district of Nagaon in Assam. Of the total sample farmers of 121, he found 28.92 percent as self-users and sellers and 7.43 percent self-users, sellers and buyers and 4.95 percent self-users and buyers and 38.01 percent only buyers. The study indicated that of the total

sample as high as 75 percent farmers participated in the water transaction. Majority of farmers (65.57 percent) purchased water both in kind and cash, 27.87 percent buyers purchased water in cash and the rest 6.56 percent purchased water in kind. One interesting finding of his study is that transaction of the water markets was based on area approach. He observed that utilisation rate of the Shallow Tubewells (STWs) based schemes were relatively higher and the emergence water markets had facilitated better utilisation of irrigation potential regardless of small size of land holdings. However, he advocated for some regulations, because he apprehended that due to open access nature of groundwater resource in the state and profit maximising motive of the sellers, water market might result in overexploitation of the groundwater.

Manonmani and Malathi (2012) have carried out a study on water market in the four villages of Panruti Block of Cuddalore District of Tamil Nadu. In their study they found that under output sharing buyers pay higher water prices to sellers than under other type. Small farmers, being unable to invest on their own tube-well, always turned out to be the buyers of water. The study suggested that if formal credit facilities were advanced to these small farmers, they could have invested on installation of pumpsets which would make groundwater prices more competitive. They viewed that informal groundwater market would become more effective if sufficient number of potential sellers existed.

Khair et al. (2012) made an analysis on informal groundwater marketing in upland Balochistan, Pakistan using quite a large number of sample of 328 water sellers and buyers. The study evaluated the groundwater trading mechanism and then empirically examined factors affecting the groundwater trading using logit econometric models. The major findings include the following: (a) groundwater exchange takes place on temporary basis; (b) Two common transactions methods were noted – water in exchange for given crop share (60 percent of the total samples) and cash payment per hour (flat rate per hour); (c) The charges per hour depend on the altitude, with an average price of Rs. 100, Rs.112, and Rs.205 per hour were reported at low, medium and high altitudes respectively; and (d) The results of empirical models indicates that among others, cropping intensity, area under high value fruits, decline in water table, tubewell reliability, alternate source of irrigation, and soil quality are important variables influencing water buying and selling

decisions. Importantly, personal attributes such as kinships, age, and education were also found important factors affecting water buying and selling decisions. In addition, the study notes the benefits of water trading in the study area in the sense that water market appears to provide cushions against increasing water scarcity by averting damages to high value horticultural crops and also proving useful in enhancing water efficiently as it helps overcome the problem of over irrigation/misuse of water by facilitating selling the surplus/extra water and using purchased water more sparingly and efficiently.

Banerji et al. (2012) made an analysis on institutions and informal markets that govern groundwater allocation in a sugarcane-cultivating village in Baghpat district of Western Uttar Pradesh, India. They found that though there is a uniform village level water price which has no bearing on the marginal value product of water social contract results in efficient allocation of water across farmers' plots. Since inadequate supply of power has remained as one of the major causes adversely affecting the production, their analysis shows that an alternative regime of pricing power and supplying it reliably can increase sugarcane output up to 9 percent resulting in farm products being more than sufficient to cover the marginal cost of providing water. Though devising out a higher price-reliable supply power policy is desirable, they felt the necessity of discussion on public versus private ownership of power supply and regulation as they only empirical proved that such a policy regime can give more reward.

2.2.2 Determinants of Groundwater Markets:

It is clear from the previous discussion that a number of factors which have both market and non-market dimension, affect functioning of groundwater markets. Apart from farm specific factors, a number of social factors also largely affect groundwater transaction between farmers. A few studies have examined these factors influencing water buying and selling decisions in a more systematic manner. These include Saleth (1996), Bhandari and Pandey (2006), Singh and Singh (2006), Sharma and Sharma (2006), Khair et al. (2012), etc. Following is the brief review of these studies.

Bhandari and Pandey (2006) in an attempt to examine the economics of groundwater irrigation and determinants of tubewell ownership decision using farm-level data collected from 324 households in Nepal, found that STW irrigation has made a

significant positive effect on rice yield, input productivity and farmer's incomes. They reiterated the role of water market (though underdeveloped) in spreading these benefits widely among small holders who finds ownership of pumpsets economically not viable. Based on probit model they listed out that the farm size, land fragmentation, access to electricity and access to credit are important determinants of STW ownership by a farmer. To make groundwater irrigation more beneficial to the poor farmers, they emphasised on revamping credit policy, investments in rural electrification, land reforms such as consolidation of land holdings, etc.

Singh and Singh (2006) with 180 sample farm households from the Meerut district of Uttar Pradesh examined the structure, determinants and efficiency of the groundwater markets of the state. The study concluded that there is an inverse relationship between the number of buyers and the farm-size. However, for the sellers the relationship is just the opposite. The electric powered WEMs dominate the groundwater irrigation though buyers have access to both diesel operated and electric tubewells. Among the others, the study has identified that the buying of groundwater is favoured by the farmers with small size and fragmented holdings, low education attainment and less probability of joint-ownership of a WEM.

Sharma and Sharma (2006) in their study on water market conducted in the arid and semiarid zones of Rajasthan, India have addressed the emerging issues of exploitation of the buyers of water (i.e. resource-poor, small farmers), environmental as well as social concerns for the activities of sellers. The study re-affirmed that the credit policies and the power pricing policies of the government were helping in the unsustainable and inequitable use of this resource. The study felt the need of a comprehensive water policy ensuring mandatory recharging of the abandoned wells mainly for the sellers of water is the need of hour for the efficient and sustainable use groundwater. The analysis of farmers' decision to participate in water markets employing logit regression has suggested that the farmers having higher fragmented landholdings have higher probability of buying groundwater. Since, joint ownership of wells is negatively associated with the farmers' probability of buying groundwater, the study has conclude that the consolidation of holdings or installing cooperative wells may economise the irrigation investment and lead to efficient management of resources of the farmers and sustainable utilisation of water.

Khair et al. (2012) made an analysis on informal groundwater marketing in upland Balochistan, Pakistan using quite a large number of sample of 328 which include both water sellers and buyers. The study evaluated the groundwater trading mechanism and then empirically examined the factors affecting groundwater transaction using logit econometric models. The results of the logit models indicate that among others, cropping intensity, area under high value fruits, decline in water table, tubewell reliability, alternate source of irrigation, and soil quality are important variables influencing water buying and selling decisions. Importantly, personal attributes such as kinships, age, and education were also found important factors affecting water buying and selling decisions. In addition, the study notes the benefits of water trading in the study area in the sense that water market appears to provide cushions against increasing water scarcity by averting damages to high value horticultural crops and also proving useful in enhancing water efficiently. The study has found that water market has helped in overcoming the problem of over irrigation or misuse of water by facilitating sale of surplus water and using purchased water more sparingly and efficiently.

2.2.3 Reliability of Groundwater Markets:

Above discussion on the structure and functioning of groundwater market reveals that the market is residual as water sellers usually sell water to the buyers after meeting their own requirements. This, in turn, results in inadequate supply of water in buyers' fields making the market unreliable for the buyers. At the same time, the sellers might also face the problem of availability of sufficient water for both own use and sale owing to scarcity of water [in water scarce region already pointed out by a few studies, e.g., Saleth (1998)]. The situation of insufficient availability of water to the sellers and inadequate provisioning of water to the buyers is discussed as reliability of groundwater markets. Thus, studies on water markets have discussed the issue of reliability of water market from both buyers and sellers' perspectives. Almost all studies on water market have highlighted this issue of reliability as an important dimension of water markets. However, studies that specifically focus on reliability of groundwater market in ensuring adequate supply of water to the buyers are very limited. Following is the review of studies which have systematically dealt with the issue of reliability of water markets.

The question of reliability though has been raised in almost all studies on groundwater market (as the issue is intrinsically linked with operation of the market) Meinzen-Dick (1998) took up the study of reliability more systematically. Meinzen-Dick (1998) in a study to examine reliability of water markets and the impact of water markets on agricultural productivity in Pakistan, found that private groundwater market was a less reliable source groundwater during the period when the farmers needed it the most. From sellers' point of view, groundwater markets were more unreliable during electricity shortages and peak water demand. But from buyers' point of view, a host of factors, combined together, worked in determining reliability of water markets. Based on a logistic regression model, Meinzen-Dick found that capacity of the tubewells, social status of the buyers and age of the buyers are significant factors of reliability of groundwater markets.

Singh and Singh (2003) in their study on groundwater market based on a sample of 180 farms from Meerut district of Western Uttar Pradesh (undivided) found a large proportion of sample farm households (82 percent) entering in water markets either fully or partly. Regarding reliability of groundwater market, the study concluded that the groundwater market was less reliable for buyers compared to the owner-cum-sellers. Further, electricity operated WEMs had been found less reliable than the diesel operated WEMs as the former were subject to higher breakdown and erratic electricity supply.

Hussain et al. (2005) in their study on water market in Pakistan found that the market for groundwater unreliable for the buyers. According to them buyers found the market unreliable if they bought water from small-capacity, electric powered tubewells. In order to improve reliability of water they emphasised the importance of increasing tubewell density by assisting small and marginal farmers to purchase tubewells. They were also of the opinion that regular supply of electricity could help in getting an access to reliable supply of water.

2.2.4 Efficiency of Groundwater Markets:

As discussed in chapter one, groundwater market is viewed as an institution which ensures efficiency in water use. Thus, farmers who participate in groundwater transaction are expected to make efficient use of water than those farmers remaining outside the market. However, due to unreliable nature of the market, there are

uncertainties and inadequate provisioning of water in the crop field of buyers. This, in turn, leads to differences in the attainment of technical efficiency between buyers and sellers plots. This issue of water use efficiency has been taken up for empirical investigation in recent studies on water markets. However, studies on the issue of economic efficiency of water use under a groundwater market are also very limited. A few scientific studies are available in this regard for example, Manjunatha et al. (2010, 2011a), Srivastava et al. (2009), Chowdhury (2009, 2010), Khanna (2006) and Deepak (2005).

Deepak et al. (2005) based on primary data collected from 120 groundwater users in eastern dry zone of Karnataka, have compared water use efficiency among different categories of water users, viz. well owners who do not sell water, well owners who sell water either for agricultural or non-agricultural use and water buyers (both agricultural and nonagricultural). The study found that the groundwater market helped spreading access to irrigation for those who do not own well. While the water buyers are found to be achieving higher water use efficiency, water sellers realised higher marginal productivity of water than farmers who did not sell water. Farmers participating in the groundwater market are more efficient in water use in addition to conserving groundwater than those who are not participating. Groundwater markets are thus promoting efficiency in groundwater use and, in addition, are a conservation strategy for scarce groundwater in hard rock areas.

Khanna (2006), based on a village level survey from the Tamelagarhi village in north Indian state of Uttar Pradesh (UP) estimated technical efficiency at the plot level by ownership types of water amongst a cross section of sugar cane growing farmers. Employing the stochastic production frontier, maximum likelihood estimates were obtained and found that estimated technical efficiency scores are highest on plots where water is sourced from a privately owned tubewell, followed by plots serviced by joint ownership of tubewells and the lowest on plots where water is bought. Income gains from improved efficiency was found to be the largest of ₹ 1, 082 per *bigha* (one *bigha* is equivalent to 0.133 hectare) estimated for buyers' plots and ₹ 649 per *bigha* for plots with their own tubewell with the average of ₹ 867 for all plots. Modeling inefficiency effects as a function of farm specific explanatory variables, the study identified

education, land area, discharge of tubewell and distance of plots from the water source as the determinants contributing to technical efficiency.

Srivastava et al. (2009) conducted a study on impact of groundwater market on water use efficiency with primary data collected from 100 farm households in the Central Plain Zones of Uttar Pradesh. The estimates of Data Envelopment Analysis showed that both buyers and owners of WEMs were technically inefficient in water-use, as the actual use of irrigation water was found much higher than the optimum level. However, 'buyers' were found comparatively more efficient than 'owners' in water utilisation. They concluded that for efficient use of groundwater, groundwater market can emerge as a better tool for improving the efficiency of irrigation water across farm-sizes and crops.

Manjunatha et al. (2009, 2011a, 2011b) using a sample of 90 farms in hard areas of India, containing water sellers, water buyers and control farmers for the reference year of 2007-08, studied the effect of groundwater market on the efficiency of water use employing Data Envelopment Analysis (DEA). The study found that water buyers use water more efficiently than the sellers, while sellers were found more efficient than the farmers in the control group (farmers who are neither buyers nor sellers) efficient. Using a Kruskal-Wallis test, differences in average efficiency between these groups are shown to be statistically significant. Based on their finding they concluded: (a) groundwater markets could add to improving efficiency of water use; and (b) existence of groundwater markets offers access to groundwater to resource poor farmers, the opportunity to benefit from the improved agricultural productivity generated by irrigation.

Chowdhury (2010) examined the marginal productivity of water and other inputs in dry season rice (*boro* rice) production in Bangladesh using a data set collected by the International Rice Research Institute (IRRI) from a nationally representative sample of farm households in Bangladesh. The main focus of the study is to estimate efficiency of irrigated water used in *boro* rice production. Estimating a translog production function for *boro* rice in seven hydrological regions of Bangladesh the findings of the study suggest that irrigation water is quite inefficiently used in Bangladesh agriculture, particularly in comparison with other inputs.

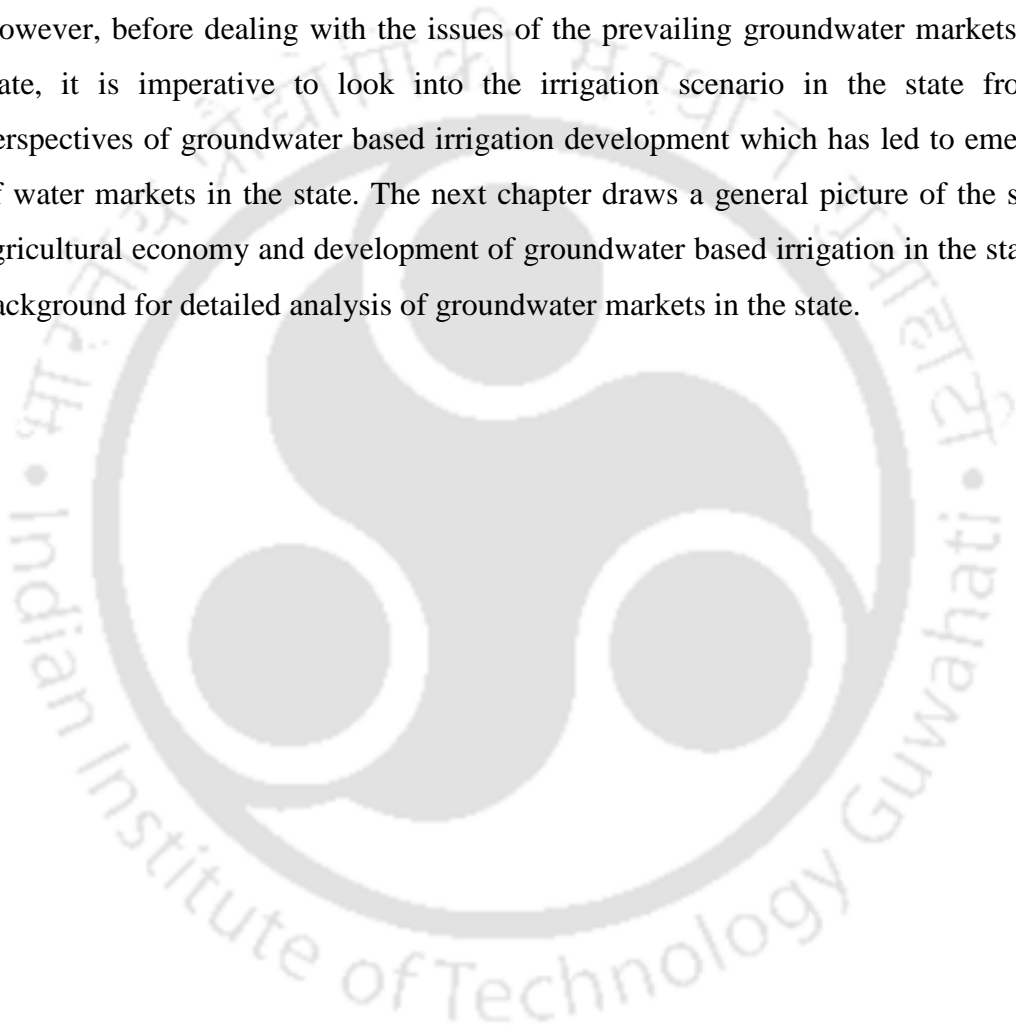
2.3 Summing Up:

From the above discussion it is clear that for an effective management of groundwater, there is a need for designing an appropriate institution. Of the institutions, water markets although have emerged and gained importance in allocating water among numerous farmers, researchers show apprehension that in the absence of a well-defined property rights unregulated water market may lead to aquifer depletion. As a result this institution may fail to address sustainable management of groundwater. But interestingly studies have failed to establish the link and viability of defining property rights (except a few such as Vaidyanathan 1996) in the context where numerous farmers are engaged in the trade. Thus, it warrants proper understanding of prevalent formal and informal institutions governing water use in general and groundwater in particular.

Regarding functioning of the water markets, it is clear that most of the studies deal more with the structure and functioning of the markets such as size of the market, characteristics of buyers and sellers, types of water transaction, rate of water charges, nature of the market whether monopolistic or competitive, equity implication of access to groundwater, reliability of water market and water use efficiency of farmers, etc. Studies which have systematically and rigorously examined the issues of reliability and water use efficiency are very limited in number. Further, most of the studies on water markets are conducted in the water scarce region. As a result, water scarcity and resultant effects on the market in delivering water at prices close to average costs drew more attention. The studies on water markets examining the issues of water market in water abundant regions are very limited. Moreover, intensive investigation into the issues of reliability and efficiency stemming from access to water in water abundant regions are few. Though in all studies reliability of the market is mentioned to be an important issue, but under what circumstances the market turns out to be unreliable for the buyers has not been specifically discussed excepting a few. Earlier studies had pointed out that there is an interlinkage of labour market, credit market and agricultural insurance market with water market. But the link between rural market and water market has not been established in most of the studies. From the review of literature it is also found that water market is a village level localised institution and therefore, its functions depend upon the local conditions. Areas of concern of water markets (such as

energy pricing) and the policies designed to deal with these, are also different for the regions depending on availability of water. For example, when regulation of the growth of the water markets is of immense significance in water scarce region, development of the same is highly important for transforming stagnant agriculture in water abundant regions. Therefore, an investigation into the operation of groundwater markets and other important issues relating to the market in the water abundant state of Assam is felt necessary. Moreover, there is hardly any study on water markets of the state.

However, before dealing with the issues of the prevailing groundwater markets in the state, it is imperative to look into the irrigation scenario in the state from the perspectives of groundwater based irrigation development which has led to emergence of water markets in the state. The next chapter draws a general picture of the state of agricultural economy and development of groundwater based irrigation in the state as a background for detailed analysis of groundwater markets in the state.





CHAPTER THREE

DEVELOPMENT OF GROUNDWATER BASED IRRIGATION IN ASSAM

3.1 Assam: A Background

3.1.1 Location, Physical Features and Demography

Assam is located in North-Eastern part of India sharing its border with seven states - Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and West Bengal and two countries - Bhutan and Bangladesh. It is located between the latitudes of 24°08` N and 27°09` N and the longitudes of 89° 42` E and 96°10`E. With a geographical area of 78,438 km², the state occupies almost 2.4 percent of the total geographical area of the country and supports about 2.57 percent of the country's total population as per 2011 Census. The state is comprised of three broad geographical divisions, viz. the Brahmaputra Valley, the Barak Valley and the Hills. While the Brahmaputra Valley comprises about 72 percent of the total geographical area of the state, the Barak Valley and the Hills comprises 19 percent and 9 percent respectively. According to the Population Census of 2011, the population of Assam stands at 3, 11, 69, 272 of which 51.18 percent are males and the remaining 48.81 percent are females. The decadal population growth rate of the state is 16.93 percent during 2001-2011 against 17.64 percent for the country as a whole. The sex-ratio of the state is 954. The density of population of the state is 397 against India's density of 382 as per 2011 Census. The literacy rate of the state is 73.81 percent with the male literacy rate of 78.81 percent and female literacy rate of 67.27 percent.

3.1.2 Economy of the State:

The economy of Assam is primarily rural and agrarian in nature. As per Population Census 2011, the rural population of the state is 86 percent of the total population which is much higher than that for India (69 percent). The Net State Domestic Product (NSDP) of the state at current prices (Advanced Estimates) is estimated at ₹ 13, 1014 crore in 2012-13. NSDP in the state registered an annual growth of 14.23 percent compared to 13.26 percent growth in Net Domestic Product (NDP) of the country as

whole during 2012-13. The Per Capita Income (PCI) of Assam at Constant Prices (in 2004-05) in 2012-13 was ₹ 24, 192 which was about 38 percent less than the PCI of ₹ 39,143 for the country as whole. If we look at sectoral composition of GSDP of the state, we find that services sector accounted for the largest share of 56 percent in 2011-12 followed by industrial sector at 22 percent and agriculture and allied sector at 22 percent. In fact, the contribution of services sector has been rising and it registered a rapid growth in recent years. The advanced estimates for the year 2012-13 showed that services sector in constant prices (2004-05) registered a growth of 9.30 percent while the growth rate of industry and agriculture and allied services stood at 3.66 percent and 3.80 percent during 2012-13 (Govt. of Assam, 2013b). Agriculture and allied sector contributed a major share to the Net State Domestic Product (NSDP) of the state which was almost 61 percent (at current prices) during 1950-51. However, the sector's contribution to the state's NSDP has been declining sharply over the subsequent years. For instance, it declined from nearly 60 percent in 1950's to nearly 50 percent in 1980's and to only about 30 percent by the end of 1990's. The contribution of this sector to NSDP of the state was 26.21 percent (at current prices) and 27.04 percent (at constant 1999-2000 prices) in 2010-11.

Though, the share of services sector in GSDP of the state has gone up in recent years, the significance of agriculture and allied sector (comprised of agriculture, forestry and logging, fishery and mining and quarrying) has not reduced much. More than 75 percent of the population are directly or indirectly dependent on agriculture and allied activities as a source of income. According to Population Census 2001, nearly 53 percent of the total working force has been engaged in agriculture. As per the land utilisation statistics for the year 2010-11, out of the total 78.44 lakh hectares of geographical area of the state, the Gross Cropped Area (GCA) for the year 2009-10, is 41.59 lakh hectares (which is 53.02 percent of the total geographical area and 67.56 percent of the GCA). The Net Sown Area (NSA) is 28.10 lakh hectares (which is 35.82 percent of the total geographical area and 71.71 percent of the GCA). The percentage of area sown more than once is estimated at 48.00 percent for the year 2010-11 (Govt. of Assam, 2013a). The cropping intensity of the state for the year 2009-2010 is 146 percent.

3.1.3 Land-use Pattern:

There is a preponderance of small and marginal farmers in the state. According to the Agricultural Census 2010-2011, there were 27.50 lakh operational holdings in the state covering an area of 29.99 lakh hectares (Govt. of Assam, 2013a). Out of this total number of operational holdings, marginal holdings (below 1 hectare) accounted for 63.4 percent followed by small holdings (1 to 2 hectares) which account for 21.49 percent of the total land holdings. These two major groups also accounted for 21.30 percent and 23.50 percent respectively, of the total operational areas of the state. On the other hand, the large holding (10 hectares and above) constituted only 0.18 percent of the total number of operational holdings and 8.40 percent of the total cropped area of the state. The average size of operation holdings was 1.15 hectares in 2001-02 which further declined to 1.10 hectares in 2010-11 (Agricultural Census 2010-11, Govt. of Assam, 2013a). Another important feature revealed by Agricultural Censuses of the state is that over the successive Censuses the total area of operational holdings in the state has been declining. Both the number and area of small and marginal holdings have been increasing, for instance, the number of marginal holdings in 2001 Census increased by 0.69 percent over 1995 Census and the area of operational holdings in 2001 Census increased by 7.50 percent over 1995 Census.

3.1.4 Cropping Pattern:

The cropping pattern of the state is mainly dominated by rice. Rice occupied about 90.05 percent of the total net cropped area and about 61.02 percent of the gross cropped area during the year 2011-12. The share of rice in total area under foodgrains production stood at 92.80 percent leaving share of other cereals comprising of wheat, maize, other cereals and millets to be commanded by only 7.20 percent. The rice crop in Assam is classified into three categories depending on the season in which the crop is harvested (Bezbaruah, 1994; Dutta, 2011), viz. autumn rice, winter rice and summer rice. Among the three, in terms of area, winter rice (the principal *kharif* crop of the state) constitutes the highest percentage (about 72.30 percent) of the total area under rice (Govt. of Assam, 2013a). Compared to the area under winter rice, the total area under autumn and summer rice, combined together, is much smaller. In 2010-11, the total area under these two crops was 6, 70,000 hectares which is about 26.31 percent of the total area under rice in the state (Govt. of Assam, 2013a). However, there has been

a gradual decline in the area under autumn rice, which has switched over to the summer rice. During 2005-06, the area under autumn rice was 3.98 lakh hectares which declined to 3.79 lakh hectares during 2006-07 and 3.13 lakh hectares during 2010-11. However, the area under summer rice had increased marginally to 3.23 lakh hectares during 2007-08 then to 3.99 hectares during 2011-12. The area under summer rice is increasing because of its high productivity and development of groundwater based irrigation in the state. Cultivation of summer rice, locally known as *boro* rice in the state is an age old practice, particularly in logged, low lying or medium lands with irrigation during November to May. The cultivation of summer rice is also spreading even to those non-traditional areas where irrigation is available.

3.1.5 Farm Mechanisation, Use of HYV, Fertiliser, etc.:

The use of modern technology in agriculture is not noteworthy in the state. The farm power availability in 2012-13 is about 1.02 hp per hectare in the state as compared to 2.05 hp per hectare at the national level. This farm power is generated through more than 6,143 numbers of tractors and 23,627 numbers of power tillers which are already distributed to farmers till 2011-12. However, the use of other machineries such as power paddy thresher, hand compressor sprayer, etc. in agriculture is still very low (Govt. of Assam, 2013b). The area coverage under High Yielding Variety (HYV) rice was 66.70 percent in the total area under rice during 2011-12. The area under HYV rice has been showing a gradual increase over the years. The total area under HYV of rice (autumn, winter and summer), which stood at 12.01 lakh hectares during 1996-97 increased to 14.29 lakh hectares during 2001-2002 and 14.35 lakh hectares in 2002-03 and 15.13 lakh hectares in 2008-09 and 16.98 lakh hectares in 2011-12. The fertiliser consumption in the state in terms of nutrient (N+P+K) per hectare is much lower than the national figure. According to the state Agriculture Department, consumption of fertiliser in the state was 74.58 kg per hectare against the national average consumption of 117.07 kg per hectare during the year 2011-12. However, the trend of per hectare consumption of fertiliser increased more than 30 percent during the period 2008-09 to 2011-12. In association with chemical fertilisers, the use of bio-fertilisers and organic manure has been increased in the state especially by the Department of Agriculture under the programme “Input support to the agriculturalists having Kisan Credit Card (KCC)”. The total amount of bio-fertiliser and organic manure consumption was

estimated to be 175 metric ton and 2.80 lakh metric tons in the year 2010-11 (Govt. of Assam, 2013b). The irrigation infrastructure in Assam is not satisfactory. In 2010-11, only in 29.20 percent of the net sown area in the state, the created irrigation potential was utilised (Govt. of Assam, 2013a). Available estimates for the year 2000-01 by the Ministry of Agriculture, Govt. of India show that the percentage of Net Irrigated Area (NIA) to the Net Sown Area (NSA) was 6.22 percent against 83.90 percent in Haryana, 84.47 percent in Punjab, etc. The state report on Agriculture Census, 2005-06 states that the total NIA of the state is 1, 45, 702.20 hectares of which 11.45 percent is served by tubewells. The state of development of irrigation in the state is taken up for a detailed discussion in the next section.

3.1.6: Total Rainfall:

Bulk of the water in the state, both surface and groundwater is obtained from rainfall. Assam experiences the predominant influence of the south-west tropical monsoon which reigns from April to October with occasional winter showers. The low clouds of the southwest monsoon after being intercepted by the N.C. Hill range and Naga Patkai range, cause heavy rainfall in the southern part of Assam and precipitate in the Brahmaputra valley, their intensity increasing towards the foothills of the Himalayas. The approach of the monsoon is marked by strong winds, overcast skies and occasional thunder showers, hailstorm and cyclones during April and May with heavy showers from June.

The season-wise normal rainfall pattern of the state is like this: Winter season (December, January & February) 66.20 mm, Summer season (March, April & May) 648.90 mm, Monsoon season (June, July, August and September) 1702.00 mm, Post monsoon season (October and November) 167.40 mm, Annual 2584.50 mm. On an average the annual rainfall in the State varies from 1780 to 3050 mm with 144 rainy days (Govt. of Assam, 2013b). Out of the total rechargeable amount of groundwater in the state about 95.01 is contributed by rainfall.

However, the state recorded a decline in annual rainfall resulting in drought like situation in many districts of the state over the years. For example, the total rainfall in Assam declined from 3, 188.40 mm in 1974 to 2, 367.93 mm in 2005 then to 1,951.30

mm during 2008-2009. The state had experienced 2, 275.90 mm of rainfall during 2010-11 with a normal pattern in the year.

On the whole, it can be concluded that agriculture in Assam is mostly underdeveloped with widespread practice of traditional farming techniques and correspondingly low usage of modern farm inputs, low levels and lower growth in productivity and production in the sector, widespread prevalence of subsistence cultivation, poor/inadequate agricultural infrastructure and inadequate irrigation development and so on. In terms of production of various crops, Assam is below the national average in most cases with the exception of horticultural crops (Govt. of Assam, 2013b). Considering this, government of India has duly recognised the need of extending green revolution to the North East and Assam in particular. However, the availability of assured irrigation is the most important pre-requisite for a sustained development in agriculture. The status of irrigation development of the state is discussed in the following section. Irrigation, however, critically depend on endowment of water resources. In the following section, a brisk account of total available water resources in the state is made.

3.2 Total Water Resources in the State:

Assam has different agro-climatic and hydrological conditions, especially in terms of water resources compared to other parts of the country. The state is richly endowed with water resources. The sources of water resources in the state can be divided into two types: (i) surface water flow constituted by two major rivers, viz. the Brahmaputra and the Barak along with their numerous tributaries and streams, and surface water stock in various ponds and lakes, and (ii) abundant groundwater reserves. In the following sub-sections, the availability of these sources of water in the state has been assessed.

3.2.1 Surface Water Availability:

The surface water resources of the state as a whole are substantial. About 8, 251 km² (10.5 percent) of the total geographical area of the state, is occupied by the surface water bodies. Out of this, about 6, 503 km² is occupied by the river systems including the Brahmaputra and 1748 km² by the natural wetlands. The total surface water of the

state is estimated at about 600 billion meter³ (Draft Water Policy, Govt. of Assam, 2007). The two river basins of the state (i.e. the Brahmaputra and the Barak) account for as high as 32 percent of the country's total surface water potential (Dutta, 2011).

3.2.2 Groundwater Availability

Assam is richly endowed with groundwater reserves. According to the Central Groundwater Board (CGWB) (2006), the net availability of annual replenishable groundwater in the state stands at 24.89 bcm (which is about 6.23 percent of the total groundwater reserves of the country). After leaving aside about 23.70 percent for domestic and industrial uses, an amount of 19.06 bcm (76.57 percent of the total available reserves) is available for irrigation. Out of the total available annually replenishable groundwater reserves, about 22 percent have already been drafted for all purposes (industrial, domestic and agriculture). This figure is, however, very low compared to about 61 percent for the country as a whole. In some states, the total development has already exceeded its annual replenishable level which for example, 170 percent in Delhi, 145 percent in Punjab, 107 percent in Haryana, etc. The total replenishable groundwater resources and the level of groundwater development in different states of the country are presented in Table 3.1.

Table 3.1

State-wise Groundwater Resources Availability, Utilisation and Stages of Development in India (in bcm)

Sl. No	States/union Territories	Annual Replenishable Groundwater Resource					Natural Discharge during non-monsoon season	Net Annual Groundwater Availability	Annual Groundwater Draft			Projected demand for Domestic and Industrial uses up to 2025	Groundwater Availability for Future Irrigation	Stage of Groundwater Development
		Monsoon Season		Non-monsoon season		Total			Irrigation	Domestic and industrial uses	Total			
		Recharge from Rainfall	Recharge from other sources	Recharge from Rainfall	Recharge from other sources									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
States														
1	Andhra Pradesh	16.04	8.93	4.20	7.33	36.50	3.55	32.95	13.88	1.02	14.9	2.67	17.65	45
2	Arunachal Pradesh	1.57	0.00009	0.98	0.0002	2.55	0.26	2.3	0.0008	0	0.0008	0.009	2.29	0.04
3	Assam	23.65	1.99	1.05	0.54	27.23	2.34	24.89	4.85	0.59	5.44	0.98	19.06	22
4	Bihar	19.45	3.96	3.42	2.36	29.19	1.77	27.42	9.39	1.37	10.77	2.14	15.89	39
5	Chhattisgarh	12.08	0.43	1.30	1.13	14.94	1.25	13.68	2.31	0.48	2.80	0.70	10.67	20
6	Delhi	0.13	0.06	0.02	0.09	0.30	0.02	0.28	0.2	0.28	0.48	0.57	0.00	170
7	Goa	0.22	0.01	0.01	0.04	0.28	0.02	0.27	0.04	0.03	0.07	0.04	0.18	27
8	Gujarat	10.59	2.08	0.00	3.15	15.82	0.79	15.02	10.49	0.99	11.49	1.48	3.05	76
9	Haryana	3.52	2.15	0.92	2.72	9.31	0.68	8.63	9.1	0.35	9.45	0.60	-1.07	109
10	Himachal Pradesh	0.33	0.01	0.08	0.02	0.44	0.04	0.39	0.09	0.02	0.12	0.04	0.25	30
11	Jammu and Kashmir	0.61	0.77	1.00	0.32	2.70	0.27	2.43	0.10	0.24	0.33	0.42	1.92	14
12	Jharkhand	4.26	0.14	1.00	0.18	5.58	0.33	5.25	0.70	0.38	1.09	0.56	3.99	21
13	Karnataka	8.17	4.01	1.50	2.25	15.93	0.63	15.3	9.75	0.97	10.71	1.41	6.48	70
14	Kerala	3.79	0.01	1.93	1.11	6.84	0.61	6.23	1.82	1.1	2.92	1.40	3.07	47
15	Madhya Pradesh	30.59	0.96	0.05	5.59	37.19	1.86	35.33	16.08	1.04	17.12	1.74	17.51	48
16	Maharashtra	20.15	2.51	1.94	8.36	32.96	1.75	31.21	14.24	0.85	15.09	1.52	16.10	48
17	Manipur	0.20	0.005	0.16	0.01	0.38	0.04	0.34	0.00	0.0005	0.002	0.02	0.31	0.65
18	Meghalaya	0.79	0.03	0.33	0.005	1.16	0.12	1.04	0.00	0.002	0.002	0.10	0.94	0.18
19	Mizoram	0.03	0.00	0.02	0.00	0.05	0.004	0.04	0.00	0.0004	0.0004	0.0008	0.04	0.9
20	Nagaland	0.28	0.00	0.08	0.00	0.36	0.04	0.32	0.00	0.009	0.009	0.03	0.30	3

Table 3.1
State-wise Groundwater Resources Availability, Utilisation and Stages of Development in India (in bcm)

Sl. No	States/union Territories	Annual Replenishable Groundwater Resource					Natural Discharge during non-monsoon season	Net Annual Groundwater Availability	Annual Groundwater Draft			Projected demand for Domestic and Industrial uses up to 2025	Groundwater Availability for Future Irrigation	Stage of Groundwater Development
		Monsoon Season		Non-monsoon season		Total			Irrigation	Domestic and industrial uses	Total			
		Recharge from Rainfall	Recharge from other sources	Recharge from Rainfall	Recharge from other sources									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
21	Orissa	12.81	3.56	3.58	3.14	23.09	2.08	21.01	3.01	0.84	3.85	1.22	16.78	18
22	Punjab	5.98	10.91	1.36	5.54	23.79	2.33	21.44	30.34	0.83	31.16	1.00	-9.89	145
23	Rajasthan	8.76	0.62	0.26	1.92	11.56	1.18	10.38	11.60	1.39	12.99	2.72	-3.94	125
24	Sikkim					0.08	0	0.08	0.00	0.01	0.01	0.02	0.05	16
25	Tamil Nadu	4.91	11.96	4.53	1.67	23.07	2.31	20.76	16.77	0.88	17.65	0.91	3.08	<i>Contd.</i>
26	Tripura	1.1	0.00	0.92	0.17	2.19	0.22	1.97	0.08	0.09	0.17	0.20	1.69	
27	Uttar Pradesh	38.63	11.95	5.64	20.14	76.36	6.17	70.18	45.36	3.42	48.78	5.30	19.52	70
28	Uttaranchal	1.37	0.27	0.12	0.51	2.27	0.17	2.1	1.34	0.05	1.39	0.08	0.68	66
29	West Bengal	17.87	2.19	5.44	4.86	30.36	2.9	27.46	10.84	0.81	11.65	1.24	15.32	42
	Total States	247.88	69.51509	41.84	73.155	432.200	33.73	398.70	212.38	18.04	230.44	29.12	161.92	58
Union Territories														
1	Andaman & Nicobar						0.005	0.320	0.000	0.000	0.010	0.008	0.303	4
2	Chandigarh	0.016	0.001	0.005	0.001	0.023	0.002	0.020	0.000	0.000	0.000	0.000	0.020	0
3	Dadra & Nagar Haveli	0.059	0.005			0.064	0.003	0.060	0.001	0.007	0.009	0.008	0.051	14
4	Daman & Diu	0.006	0.002	0	0.001	0.009	0.0004	0.008	0.007	0.002	0.009	0.003	-0.002	107
5	Lakshadweep					0.000	0.009	0.004	0.000	0.002	0.002			63
6	Pondicherry	0.057	0.067	0.007	0.029	0.160	0.016	0.144	0.121	0.030	0.151	0.031	-0.008	105
	Total UTs	0.138	0.075	0.012	0.031	0.26	0.036	0.556	0.129	0.051	0.181	0.050	0.365	33
	Grand Total	248.02	69.59009	41.852	73.19	433.02	33.77	399.25	212.51	18.09	230.62	29.17	162.29	58

Source: Dynamic Groundwater Resources of India (as on March 2004), Central Groundwater Board, Ministry of Water Resources, 2006.

It is clear from Table 3.1 that out of the total groundwater development, as much as about 89.15 percent is used for agricultural purpose and the remaining 10.84 percent is used for both domestic and industrial purposes in the state. Since development of groundwater in Assam is in the safe zone (as none of the blocks is either over exploited or dark) it can be harnessed to a great extent in order to enhance irrigation facilities in the state. The state-wise distribution of blocks categorised as overexploited and dark in terms of groundwater table is presented in Table 3.2.

Table 3.2
Number of Blocks/Talukas/Watersheds Categorised as Over-exploited and Dark in Different States of India

Sl. No.	States	Nos. of Blocks/ Talukas/Watersheds	Over-exploited		Dark/Critical	
			Nos.	%	Nos.	%
1	Andhra Pradesh	1157	118	10.20	79	6.83
2	Arunachal Pradesh	59	0	0	0	0
3	Assam	219	0	0	0	0
4	Bihar	394	6	1.52	14	3.55
5	Chhattisgarh	145	0	0	0	0
6	Delhi	6	3	50	1	16.67
7	Goa	12	0	0	0	0
8	Gujarat	180	41	22.78	19	10.56
9	Haryana	111	30	27.30	13	11.71
10	Himachal Pradesh	69	0	0	0	0
11	Jammu and Kashmir	193	0	0	0	0
12	Jharkhand	193	0	0	0	0
13	Karnataka	175	7	4.00	9	5.14
14	Kerala	151	3	1.99	6	3.97
15	Madhya Pradesh	312	2	0.64	1	0.32
16	Maharashtra	2316	154	6.65	72	3.11
17	Manipur	29	0	0	0	0
18	Meghalaya	39	0	0	0	0
19	Mizoram	12	0	0.00	0	0.00
20	Nagaland	52	0	0	0	0
21	Orissa	314	0	0	0	0
22	Punjab	138	81	58.70	12	8.70
23	Rajasthan	237	86	36.29	80	33.76
24	Sikkim	4	0	0	0	0
25	Tamil Nadu	385	138	35.84	37	9.61
26	Tripura	38	0	0	0	0
27	Uttar Pradesh	819	2	0.24	20	2.44
28	Uttaranchal					
29	West Bengal	275	0	0	61	22.81
Total		7910	671	8.48	424	5.36

Note: Unit of assessment: Andhra Pradesh –Basin, Maharashtra –Water shed (Command and/non-command wise), Gujarat, Karnataka –Talukas, rest of the States –Blocks.

Source: Central Groundwater Board, Govt. of India.

The picture of groundwater potential and development in the state will be more comprehensive if we look at the district-wise distribution of them. The district-wise distribution of rechargeable groundwater availability and different stages of its development in the districts have been presented in Table 3.3.

It is evident from Table 3.3 that Sonitpur district has the highest annual replenishable groundwater reserves followed by Cachar district which are estimated at 2.11 bcm and 2.03 bcm respectively. However, despite the highest availability, groundwater development is the lowest at 2 percent in the Cachar district which is due to low level of use of groundwater for irrigation. Among the districts which experienced a high level of groundwater development, the highest drafting has taken place in Bongaingaon district which is estimated at 56 percent. In Morigaon district too, as high as 52 percent development of groundwater has taken place. Districts in which less than 10 percent of the total annual groundwater development has taken place include Cachar (2 percent), Hailakandi (3 percent), Jorhat (3 percent), Kokrajhar (9 percent), Karimganj (4 percent) and N.C. Hills (6 percent). Regarding use of groundwater, it is clear from the table that nearly 90 percent of the total annual groundwater draft is used for irrigation except the districts in the Barak Valley where the use of groundwater for irrigation purpose is substantially low. About 8 percent of the total draft is made in Karimganj district for irrigation purpose. This clearly indicates a low level of groundwater based irrigation development in the districts.

Above discussion clearly shows that the most of the potential of groundwater based irrigation development has not been tapped in Assam in many districts. Intuitively, it indicates that there is an ample scope of groundwater based irrigation development in the state. The unutilised groundwater can be used to irrigate an additional area of 14, 86, 461 hectares of land which is about 38 percent of the gross cropped area of the state. The scope for groundwater development is very large in the Brahmaputra Valley (Das, 1984, Dutta, 2011) compared to the other two natural divisions of the state, viz. the Barak Valley and the Hilly Regions. In the hilly regions, scope for groundwater irrigation is limited only to the small inter-mountain valleys (Dutta, 2011).

Table 3.3

District-wise Groundwater Resource Availability, Utilisation and Stages of Development in Assam (in bcm)

Sl. No	Districts	Annual Replenishable Groundwater Resource					Natural Discharge during non-monsoon season	Net Annual Groundwater Availability	Annual Groundwater Draft			Projected demand for Domestic and Industrial uses up to 2025	Groundwater Availability for Future Irrigation	Stage of Groundwater Development (in percent)
		Monsoon Season		Non-monsoon season		Total			Irrigation	Domestic and industrial uses	Total			
		Recharge from Rainfall	Recharge from other sources	Recharge from Rainfall	Recharge from other sources	Total								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Barpeta	112846	23472	0	7035	143353	7168	136186	30867	3631	34498	5959	99360	25
2	Bongaigaon	77984	16476	0	3625	98085	4904	93181	50456	2015	52471	2884	39841	56
3	Cachar	203899	22	19990	10	223921	22392	201529	52	3213	3265	5246	196231	02
4	Darrang	88222	21977	11487	5940	127626	12763	114863	43113	3314	46427	5159	66591	40
5	Dibrugarh	105325	7626	0	1766	114717	11472	103245	21609	2627	24236	3746	77891	23
6	Dhemaji	133080	3774	0	842	137696	6885	130811	11515	1258	12773	2083	117213	10
7	Dhubri	107889	12	0	4985	112886	11289	101597	12492	3632	16124	6535	82570	16
8	Golaghat	86906	5868	11557	1295	105626	10563	95064	17956	2093	20049	3139	73969	21
9	Goalpara	123115	7262	0	1608	131985	13199	118787	22204	1819	24023	3265	93318	20
10	Hailakandi	62796	210	7007	49	70062	3503	66558	634	1202	1836	2067	63857	03
11	Jorhat	106126	4325	9408	961	120820	12082	108738	13216	2257	15473	3465	92057	14
12	Kamrup	134245	24319	0	6076	164640	16464	148176	58615	5754	64369	10516	79045	43
13	Karbi Anglong	75021	2414	8168	844	86447	8645	77802	624	1804	2428	3194	73984	03

Table 3.3

District-wise Groundwater Resource Availability, Utilisation and Stages of Development in Assam (in bcm)

Sl. No	Districts	Annual Replenishable Groundwater Resource					Natural Discharge during non-monsoon season	Net Annual Groundwater Availability	Annual Groundwater Draft			Projected demand for Domestic and Industrial uses up to 2025	Groundwater Availability for Future Irrigation	Stage of Groundwater Development (in percent)
		Monsoon Season		Non-monsoon season		Total			Irrigation	Domestic and industrial uses	Total			
		Recharge from Rainfall	Recharge from other sources	Recharge from Rainfall	Recharge from other sources	Total								
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
14	Kokrajhar	166225	4622	0	686	171533	17153	154380	11577	2055	13632	3143	139660	09
15	Karimganj	64950	75	9552	31	74608	7461	67147	182	2218	2400	3853	63112	04
16	Lakhimpur	70933	3845	0	12	74790	7479	67312	9635	1965	11600	3214	54463	17
17	Morigaon	44859	7769	0	1711	54339	5434	48905	23787	1710	25497	2975	22143	52
18	Nagaon	118452.00	23713	0	5805	147970	14797	133173	59792	5147	64939	9056	64324	49
19	N. C. Hills	9719	61	1270	1	11051	1105	9946	151	424	575	745	9050	06
20	Nalbari	75750	12795.00	0	2823.00	91368	4568	86799	39070	2500	41570	3603	44126	48
21	Sibsagar	99314	4767.00	8804	1057.00	113942	11394	102547	14570	2333	16903	3623	84354	16
22	Sonitpur	179643	19395	17569	5603	222210	11111	211100	30308	3715	34023	5998	174794	16
23	Tinsukia	118066	4064	0	907	123037	12304	110733	12405	2580	14985	4257	94072	14
24	State Total (ham)	2365365	198863	104812	53672	2722712	234135	2488580	484830	59266	544096	97725	1906025	22
25	State Total (bcm)	23.65	1.99	1.05	0.54	27.23	2.34	24.89	4.85	0.59	5.44	0.98	19.06	22

Source: Dynamic Groundwater Resources of India (as on March 2004), Central Groundwater Board, Ministry of Water Resources, 2006.

3.3 Development of Irrigation Infrastructure in Assam:

Irrigation is an inevitable input of agricultural activity. Availability of assured irrigation facility is undoubtedly the most important prerequisite for use of modern technology in agriculture to enhance productivity and production in the state (Phukan, 1990, Bezbaruah, 1994, Saikia, 2008, Dutta, 2011; Govt. of Assam, 2013b). In Assam, importance of irrigation was not considered critical for carrying out agricultural activities till some years back (till 1976) as the state used to receive normal to heavy rainfall during monsoon season (Phukan, 1990; Saikia, 2008). However, in the recent years, for speedy diffusion of modern agricultural technology and to deal with the erratic and changing seasonal rainfall pattern experienced by the state, irrigation is considered highly critical. Moreover, the growing demands for foodgrains due to burgeoning population pressure also re-emphasises the demands for assured irrigation to facilitate multiple cropping across different agricultural seasons. Though about 80 percent of rainfall in the state takes place between late June and late September, the onset of monsoon and its cessation is mostly uncertain and its year to year fluctuation is also very unpredictable (Govt. of Assam, 2013b). Usually, from late September the rainfall becomes scanty and the months of November, December, January, February, and March remain practically dry except a few occasional showers. Under such circumstances, the production of *rabi* crop at a larger scale and cultivation of summer rice is very difficult during dry season from October to May without irrigation. The Government of Assam is, therefore, putting special thrust on irrigation development by harnessing the rich water resources of the state so that agricultural production and productivity can be heightened to a greater extent.

The programmes for the development of irrigation facility in Assam have been taken up under three broad schemes, viz., Major, Medium Irrigation and Minor Irrigation. This classification is based on command area of any scheme. If the command area of any irrigation scheme or project is greater than 10,000 hectares, the scheme is labeled as major schemes. While the command area of any scheme is less than 2, 000 hectares, they are called as minor irrigation schemes, any scheme with the command area lying between 2, 000 hectares to 10, 000 hectares is known as medium irrigation scheme. Based on the technology, irrigation schemes can be classified under five different

types: Surface Flow, Surface Lift, Dug well, Deep Tube Wells and Shallow Tubewells/Shallow Tube Wells. While Surface Flow and Surface Lift irrigation schemes have been exercised through major, medium and minor irrigation schemes, wells and tubewells are developed solely under minor irrigation schemes.

Three Departments are associated with the development of irrigation infrastructure in the state. These include the Department of Irrigation, the Department of Agriculture and the Department of Panchayat and Rural Development. However, while Department of Irrigation is involved in the development of all the schemes, other two are confined to execution of minor schemes like Wells, Shallow Tubewells, Low Lift Points, and Temporary Minor Irrigation Schemes only. It is worthwhile to mention that Assam State Minor Irrigation Development Corporation (ASMIDC) Ltd., set up in 1980, was also earlier closely associated with the development of minor irrigation in the state by installing Private Shallow Tubewells (STWs) and Low Lift Points (LLPs) through provision of institutional finance from National Bank for Agriculture and Rural Development (NABARD) up to 1992-93. The ASMIDC Limited has since merged with the Irrigation Department of the state. The irrigation schemes in the state are being taken up through loan assistance from the World Bank under the Assam Rural Infrastructure and Agricultural Services Project (ARIASP), from the Non-Lapsable Central Pool (NLCP) of resources with 100 percent central assistance and North Eastern Council (NEC) for creation of additional irrigation potential in the state.

3.3.1 Major and Medium Irrigation Schemes Currently in Operation:

There are 13 completed major and medium irrigation projects presently available in the state. These include *Jamuna, Sukla, Dekadong, Kaldiya, Rupahi, Kulsik, Bhumki, Horguti, Kaliabor, Longa, Bordikrai, Hawaipur* and *Dikhari* Irrigation Project. Another 7 projects under medium and major category is being constructed presently and another 7 are already proposed to be constructed in the coming years which includes 3 major, 3 medium and one inter-state projects. Apart from these, there are four ongoing major and medium projects, viz. *Dhansiri, Champamati, Borolia* and *Buridehingi* which have funded under Accelerated Irrigation Benefit Programme (AIBP). Till March 2011, 5,1729 hectares of irrigation potential has been created from through these ongoing projects (Govt. of Assam, 2013b). The particulars of major and medium irrigation (completed, ongoing and proposed) are furnished in Table 3.4.

Table 3.4
Particulars of Major and Medium Irrigation Projects in Assam (Completed, Ongoing and Proposed)

Sl. No.	Name of the Irrigation Projects	District	Classification	Types	Present Status	Irrigation Statistics			
						GCA (ha)	CCA (ha)	NIA (ha)	CI (%)
1	Jamuna	Nagaon	Major	Flow	Completed	33846	27077	25705	132.50
2	Dekadong	Barpeta and Nalbari	Major	Flow	Completed	5683	4941	4332	139.66
3	Bordikorai	Sonitpur	Major	Flow	Completed	29150	17409	16994	150.24
4	Dhansiri	Darrang	Major	Flow	Ongoing	60876	41683	41683	200.00
5	Champamati	Kokrajhar	Major	Flow	Ongoing	30000	17414	15094	165.59
6	Integrated for Kallong Basin Location	Nagaon	Major	Flow	Ongoing	29950	21450	34400	160
7	Modernization of Jamuna Irrigation Project	Nagaon and Karbi Anglong	Major	Flow	Ongoing	33876	27077	25705	163.45
8	Shukla	Kamrup	Medium	Flow	Completed	22834	16917	16072	137.00
9	Kaldiya	Barpeta	Medium	Flow	Completed	11398	9840	9716	169.20
10	Kulsik	Darrang	Medium	Flow	Completed	2000	1940	3125	156.25
11	Horguti	Karbi Anglong	Medium	Flow	Completed	3410	2735	2600	153.00
12	Rupahi	Barpeta	Medium	Flow	Completed	3932	3552	3552	160.90
13	Hawaiipur	Karbi Anglong	Medium	Flow	Completed	4259	3040	2430	160.00
14	Dikhari	Karbi Anglong	Medium	Flow	Completed	3110	2486	2360	152.00
15	Longa	Kokrajhar	Medium	Flow	Completed	4960	-	-	-
16	Kaliabor	Nagaon	Medium	Lift	Completed	13560	-	-	-

Sl. No.	Name of the Irrigation Projects	District	Classification	Types	Present Status	Irrigation Statistics			
						GCA (ha)	CCA (ha)	NIA (ha)	CI (%)
17	Bhumki	Barpeta	Medium	Flow	Completed	4200	-	-	-
18	Borbila	Baska of BTAD, Kamrup	Medium	Flow	Ongoing	12712	9717	8907	152.26
19	Pahumara	Barpeta	Medium	Flow	Ongoing	11574	9259	8333	190.85
20	Buridihing	Dibrugarh	Medium	Flow	Ongoing	5054	3050	5054	165.70
21	Borlia	Nalbari and Kamrup	Medium	Flow	Ongoing	13562	-	-	-
22	Buridihing	Dibrugarh	Medium	Lift	Ongoing	5054	-	-	-
23	Garufela	Kokrajhar	Medium	Flow	Proposed	11750	9820	5200	180
24	Burusuit	Bongaigaon	Medium	Flow	Proposed	11500	7060	6390	162.90
25	Krishnai	Goalpara	Medium	Flow	Proposed	5000	4200	3500	199.00
26	Simen	Dhemaji	Medium	Flow	Proposed	10000	7500	6830	NA
27	Puthimari	Nalbari and Kamrup	Medium	Flow	Proposed	20395	14800	13105	110.88
28	Pollah	Barpeta	Medium	Flow	Proposed	10537	8180	7000	172
29	Jiri*	Cachar and Imphal East	Medium	Flow	Proposed	7570	5750	3740	170

Note: GCA: Gross Command Area

CCA: Culturable Command Area

NIA: Net Irrigable Area

CIA: Cropping Intensity after Irrigation

* Inter-state (Assam and Manipur)

Source: Department of Irrigation, Assam, retrieved from C:\Documents and Settings\User\Local Settings\Temp\Minor.mht, accessed on 4th May, 2012.

3.3.2 Development of Minor Irrigation Schemes:

3.3.2.1 Development of Minor Irrigation under Government Sector:

The Irrigation Department of the state is in the charge of setting up of minor irrigation schemes under government sector. Up to 2007-08, the department set up a total of 1,017 numbers of minor irrigation schemes. These include different forms of minor irrigation schemes namely, surface flow, surface lift and ground water lift including Deep Tube Wells (DTW). A total of 1, 180 number of minor schemes are currently in various stages of construction. A 627 number of minor irrigation schemes have been take up to create potential of 26,378 hectares during 2006-2013 under the Accelerated Irrigation Benefit Programme (AIBP) scheme. Up to March 2011, 209 number of minor irrigation schemes under AIBP have already been constructed creating a potential of 10, 3034 hectares (Govt. of Assam, 2013b). The district-wise break up of minor irrigation schemes completed in the state and the district-wise number of ongoing minor irrigation schemes up to the year 2010-11 have been presented in Table 3.5 and Table 3.6 respectively.

Table 3.5
Summary of Completed Minor Irrigation Schemes (2010-11)

Sl. No.	Name of Districts	No. of Schemes	Estimated Potential (in ha)			Potential Created (in ha)		
			Kharif	Rabi	Total	Kharif	Rabi	Total
Plain Area								
1	Barpeta	41	11208	6058	17266	11008	5858	16866
2	Bongaigaon	39	6282	3065	9347	6282	3065	9347
3	Cachar	22	2606	1489	4095	2606	1489	4095
4	Darrang	46	21963	8444	30407	21963	8444	30407
5	Dhemaji	30	3174	2110	5284	3174	2110	5284
6	Dhubri	44	5837	5326	11163	5651	5085	10736
7	Dibrugarh	28	4881	2873	7754	4856	2858	7714
8	Goalpara	29	6774	2333	9107	6774	2333	9107
9	Golaghat	45	7939	6085	14024	7939	6085	14024
10	Hailakandi	15	2278	1340	3618	2278	1340	3618
11	Jorhat	62	6255	5896	12151	6255	5886	12141
12	Kamrup	74	8570	5068	13638	8540	5048	13588
13	Karimganj	13	973	1094	2067	973	1094	2067
14	Kokrajhar	44	11355	4780	16135	11355	4780	16135
15	Lakhimpur	48	4912	3447	8359	4912	3447	8359
16	Marigaon	33	9723	6501	16224	9723	6329	16052
17	Nagaon	46	9217	6124	15341	9217	6124	15341
18	Nalbari	47	12458	6802	19260	11128	5852	16980
19	Sivasagar	53	11903	2720	14623	11903	2720	14623
20	Sonitpur	49	21854	2419	24273	21854	2419	24273
21	Tinsukia	38	4177	1700	5877	4177	1700	5877
Total (Plains Area)		846	174339	85674	260013	172568	84066	256634
Hill Area								
22	Karbi Anglong	99	15898	5734	21632	15898	5734	21632
23	North Cachar	72	6308	340	6648	6308	340	6648
Total (Hills)		171	22206	6074	28280	22206	6074	28280
Grand Total		1017	196545	91748	288293	194774	90140	284914

Source: Department of Irrigation, Government of Assam.

Table 3.6
Summary of Ongoing Minor Irrigation Schemes (2010-11)

Serial No.	Name of District	No. of Schemes	Estimated Potential (in hectares)			Potential Created (in hectares)		
			Kharif	Rabi	Total	Kharif	Rabi	Total
1	Barpeta	52	4737	3546	8283	1209	484	1693
2	Bongaigaon	46	8347	4907	13254	1273	283	1556
3	Cachar	53	6849	8031	14880	985	700	1685
4	Darrang	86	13827	5841	19668	1986	766	2752
5	Dhemaji	33	3102	1762	4864	620	329	949
6	Dhubri	97	9547	12539	22086	1383	2474	3857
7	Dibrugarh	36	5351	2759	8110	1920	1120	3040
8	Goalpara	101	6807	5117	11924	1661	1399	3060
9	Golaghat	40	4979	3777	8756	1546	703	2249
10	Hailakandi	27	1703	971	2674	180	77	257
11	Jorhat	49	2600	1951	4551	215	103	318
12	Kamrup	82	7353	5951	13304	2848	1724	4572
13	Karimganj	38	2639	2930	5569	402	423	825
14	Kokrajhar	45	2787	1554	4341	345	51	396
15	Lakhimpur	49	3824	2710	6534	1400	860	2260
16	Marigaon	29	2168	2144	4312	507	540	1047
17	Nagaon	107	4746	3888	8634	136	239	375
18	Nalbari	55	6836	3635	10471	850	530	1380
19	Sivasagar	64	5870	2171	8041	919	428	1347
20	Sonitpur	66	4060	2353	6413	1248	810	2058
21	Tinsukia	25	2211	811	3022	75	30	105
State Total		1180	110343	79348	189691	21708	14073	35781

Source: Department of Irrigation, Government of Assam.

3.3.2.2 Development of Minor Irrigation under Private Sector:

Several initiatives have been taken under different agencies and departments to set up minor irrigation schemes in the state under private sector. The different agencies and departments of the government associated with the installation of minor irrigation schemes in the state are Assam State Minor Irrigation Development Corporation (ASMIDC), the State Agricultural Department and Panchayat and Rural Development Department.

The ASMIDC Ltd. was set up in 1980 with the financial assistance from NABARD to install shallow tubewells (STW) for utilizing groundwater and low lift points (LLP) for utilising surface water. Till 1990-91, the ASMIDC installed a total number of 49,800 STWs and LLPs under private sector. But after 1990-91 the Corporation failed to

install even a single minor scheme due to lack of institutional finance and since then it has been merged with the state Irrigation Department.

The total number of minor schemes (mainly STWs) set up by the Department of Agriculture and Panchayat and Rural Development up to 1994-95 was 27,184 and 9,247 respectively. Since 1995-96 the Department of Agriculture has set up minor irrigation schemes under different schemes: Samidhra Krishak Yojna (SKY), Assam Rural Infrastructure and Agricultural Services Projects (ARIASP), Rural Infrastructure Development Fund (RIDF), Assam Agricultural Competitiveness Projects (AACP), Disaster Management and Technology Mission, Assam Vikash Yojana (AVY), etc. These schemes are funded through Non Lapsable Central Pool of Resources (NLCPR), National Bank for Agriculture and Rural Development (NABARD), North Eastern Council (NEC). Under, the ARIASP project which was started in 1995-96 by the State Department of Agriculture, a total of 15,000 number of STWs were set up during 1999-2000. During 1997-98 to 2002-2003, 70,450 number of STWs were constructed across 21 districts in the state under ARIASP. The total irrigation potential created up to the end of 1999-2000 was 64,500 hectares from the installation of 32, 250 STWs (Dutta, 2011). The SKY scheme was started since the financial year 1999-2000 which was sponsored by NABARD under its programmes RIDF. Under this scheme, STWs to the farmers were distributed under group ownership known as Field Management Committee (FMC). In the first year of implementation of the scheme, a total of 30,000 STWs were set up in different districts of the state. During 1999-2000, NABARD under this scheme installed 90,000 STWs in different districts of the state. The Accelerated Irrigation Benefit Programme (AIBP) was initially meant for the major and medium projects only. But subsequently its coverage was extended to minor irrigation schemes also. Under these schemes, combined together, up to 30th June 2010, the state Agriculture Department has set up 2, 10, 756 number of STWs and 13, 913 number LLPs in the state. The district-wise distribution of STWs set up under these schemes up to 30th June 2010 is presented in Table 3.7.

Table 3.7

Scheme-wise Shallow Tubewells (STWs) and Low Lift Pump (LLP) Installed by Department of Agriculture in the State since Inception till 30th June, 2010

Sl No.	District	ARIASP 1997-98 to 2002-03	NABARD 1999-2002	AACP 2005-10		Disaster Management 2009-10	Technology Mission (March 2007)		Grand Total	
		STW	STW	STW	LLP	LLP	STW	LLP	STW	LLP
1	Kamrup	8841	11000	4576	1149	50	134	37	24551	1236
2	Morigaon	2658	4000	1481	118	84	50	16	8189	218
3	Karbi Anglong	240	0	446	365	18	6	68	692	451
4	North Cachar Hills	0	0	0	209	5	1	34	1	248
5	Barpeta	8328	7800	4069	466	32	28	10	20225	508
6	Nalbari	4258	8900	1565	110	22	49	5	14772	137
7	Bagsa	0	0	776	38	27	0	0	776	65
8	Nagoan	7276	11550	4555	394	63	101	145	23482	602
9	Golaghat	2461	3055	347	788	48	31	24	5894	860
10	Cachar	0	0	0	1147	33	6	69	6	1249
11	Karimganj	110	0	0	1060	11	30	52	140	1123
12	Hailakandi	50	0	10	1046	33	0	46	60	1125
13	Darrang	4800	9000	2328	270	12	65	11	16193	293
14	Udalguri	0	0	358	100	24	0	0	358	124
15	Sonitpur	3183	2830	1555	324	12	23	29	7591	365
16	Lakhimpur	1751	950	873	286	18	49	16	3623	320
17	Dhemaji	2120	520	133	788	12	44	29	2817	829
18	Bongaigaon	3739	7800	3315	320	43	33	13	14887	376
19	Chirang	0	0	1159	37	22	0	0	1159	59
20	Goalpara	3492	4500	4842	297	33	80	5	12914	335
21	Kokrajhar	1788	2400	1016	368	50	47	21	5251	439
22	Dhubri	8748	15995	4953	1301	33	83	16	29779	1350
23	Tinsukia	1373	1070	678	439	32	18	10	3139	481
24	Dibrugarh	1855	3680	674	274	12	13	12	6222	298
25	Sibsagar	1600	2450	224	327	8	70	20	4344	355
26	Jorhat	1779	1500	388	325	48	24	94	3691	467
Total		70450	99000	40321	12346	785	985	782	210756	13913

Source: Department of Agriculture, Government of Assam.

3.4 Status of Irrigation Development:

Usually, the development of irrigation is measured in terms of irrigation potential created under different schemes. Before drawing the account of irrigation development of the state, it is worthwhile to present definition of the term “irrigation potential” which is followed by the State Department of Irrigation. Following the definition given by the Planning Commission of the Govt. of India, irrigation potential is defined as the gross area which can be irrigated from a project in a design year (1st July to 30th June of the succeeding year) for the projected cropping pattern and assumed water allowances on its full development (Dutta, 2011). In the following sections, irrigation potential created under different departments has been analysed.

As per the available data, out of 41.05 lakh hectares of Gross Cropped Area (GCA) of the state, 14.77 lakh hectares of Gross Irrigation Potential (GIP) has been created up to the end of March 2011-12, which is about 35.24 percent of the GCA and 53.59 percent of the total irrigation potential (27 lakh hectares) of the state (Govt. of Assam, 2013b). Out of the GIP, a total of 6.72 lakh hectares (46.51 percent) has been created by the State Irrigation Department, 1.49 lakh hectares (10.07 percent) has been created by the by ASMIDC, 0.34 lakh hectares has been created by the Department of Panchayat and Rural Development and the rest 5.90 lakh hectares (46.25 percent) has been created by the State Agriculture Department. It is clear from Table 3.8 that about 82.42 percent of GIP has been created in the state under minor irrigation schemes, while the rest 17.58 percent has been created under the major and medium irrigation schemes solely undertaken by the government.

It is clear from Table 3.8 that the total potential created under ASMIDC up to 1992-93 has been estimated at 1, 49, 205 hectares. Out of the total potential created by ASMIDC, about 71.51 percent is created through groundwater lift schemes and the rest 28.42 percent through the surface lift points (Dutta, 2011). However, the agency has not created any additional potential since 1992-93 owing to shortage of funds. Similarly, the Department of Panchayat and Rural Development created irrigation facility of 0.34 lakh hectares up to 2001-02.

Table 3.8
Source-wise Gross Irrigation Potential Created in Assam up to 2012-13 (in hectares)

Department/Agency	Gross Irrigation Potential Created		
	2	3	4
	Major and Medium Irrigation	Minor Irrigation	Total**
Irrigation Department	254343	418655	672998(46.51)
Assam State Minor Irrigation Development Corporation (up to 1992-93)	Nil	149205	149205 (10.31)
Panchayat and Rural Development Department (up to 2001-02)		34000	34000 (2.35)
Agriculture Department	Nil	590917	590917 (40.83)
Total*	254343 (17.58)	1192777 (82.42)	1447120

* Figures in parentheses represent percentages to row total.

** Figures in parentheses represent percentage to column total.

Source: Economic Survey, Assam, 2012-13.

The irrigation facility created by the State Agriculture Department under assured irrigation programs is presented in Table 3.9.

Table 3.9
Irrigation Potential Created by the State Agriculture Department up to 2012-13

Component of Irrigation	Nos. installed		Nos. in operation		Area (in hectare)
	Diesel	Electric	Diesel	Electric	
Shallow Tube well (STWs)	288099	92907	159415	92907	504644
Low Lift Points (LLPs)	26414	10077	21330	10077	62814
Sprinkler/Drip Irrigation Set		2294		2294	2294
Flow Irrigation					5250
Micro Watershed Drainage					15915
Total					590917

Source: Economic Survey, Assam, 2012-13.

It is clear from table 3.9 that the State Agriculture Department has created irrigation potential of 5.19 lakh hectares till the end of 2011-12. The department has created the irrigation potential under minor irrigation schemes through Shallow Tubewells (85.40 percent), Low Lift Points (10.62 percent), Sprinkler/Drip Irrigation Set (0.38 percent), Flow Irrigation (0.88 percent) and Micro Watershed Drainage (2.69 percent).

The potential created under government major/medium and minor irrigation schemes by the Department of Irrigation in the state from 1990-91 to 2010-11, is shown in Table 3.10.

Table 3.10
Source-wise Irrigation Potential Created under Government
Schemes Since 1990-91 till 2011-12 (area in hectares)

Year	Major/medium	Minor	Total
1990-91	153880	272139	426019
1991-92	159440	283588	443028
1992-93	164993	290657	455650
1993-94	172763	293735	466498
1994-95	179273	297738	477011
1995-96	180113	299965	480078
1996-97	180113	300477	480590
1997-98	180113	300986	481099
1998-99	181789	303254	485043
1999-2000	188789	306953	495742
2000-01	195439	308554	503993
2001-02	202289	311052	513341
2002-03	206139	313904	520043
2003-04	210292	316430	526722
2004-05	212067	319123	531190
2005-06	214517	320695	535212
2006-07	219517	321695	541212
2007-08	222168	324291	546459
2008-09	232077	357632	589709
2009-10	239239	387470	626709
2010-11	243665	553131	796796
2011-12	254343	418955	673298

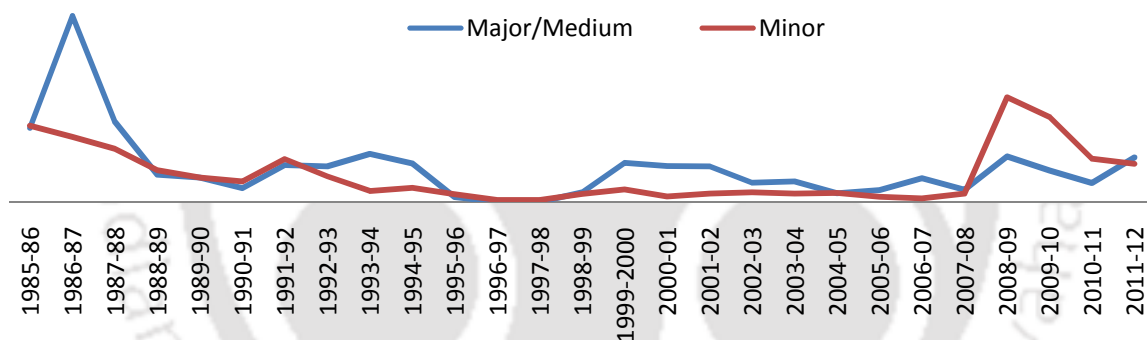
Source: Statistical Handbook, Govt. of Assam(a) for various years.

It is evident from Table 3.10 that up to 1990-91, the irrigation potential created under the minor irrigation schemes was about 63.88 percent of the total potential created up to that year. Similarly, up to 2000-01, as against the share of 38.78 percent under major/medium schemes, the share of minor irrigation schemes in the total potential created was 61.22 percent. The share of minor irrigation in the total potential created in 2011-12 has also been found to be 69.08 percent, re-emphasising that the irrigation potential created through minor irrigation schemes continued to be the dominant over that was created through the major or medium irrigation schemes till 2011-12.

If we look at the annual growth rates of the irrigation potential created by the State Irrigation Department under major/medium and minor irrigation schemes it is clear that annual growth rates of irrigation potential created under major irrigation schemes have been higher than that created under minor irrigation schemes from 1985-86 to 2007-08

after which it declined rapidly compared to minor irrigation schemes. While the annual growth rates of the irrigation potential created through major/medium irrigation schemes plummeted since 2009-10 till 2011-12, the same for minor irrigation schemes increased largely. Similarly, the compound annual growth rate for the potential created under major/medium schemes has been found almost same at 2.3 percent during 1990-91 to 2000-01 and from 2000-01 to 2009-10. But the compound annual growth rate for the potential created under minor irrigation schemes almost doubled from 1.35 percent to 2.56 percent during the same period. It is clearly understood that there has been increased dominance of minor irrigation schemes in the total irrigation potential created in the state in the late nineties.

Fig. 3.1: Annual Growth Rates of Irrigation Potential Created under Major/Medium and Minor Irrigation Schemes since 1985-86



The growing importance of minor irrigation over major/medium irrigation is felt for several reasons. As Dutta (2011) points out major/medium irrigation schemes in the state failed owing to failure in coordination among three key implementing departments/agencies, viz. namely mechanical (for maintenance of the schemes), electrical (for power supply: as per report of the government presently 126 irrigation projects are non-functional in the state due to non-payment of electricity bill.) and irrigation department; disappointment among beneficiaries regarding distribution of water between higher reach and lower reach; conveyance loss due to poor conveyance infrastructure. Saikia (2008) also notes that since nineties no notable effort has been made for the development of medium and major irrigation sources due to the problem of water distribution, operation and maintenance of the system. Compared to problems associated with major and medium irrigation schemes, the groundwater based minor

irrigation schemes are not only affordable and easily accessible for the small farmers but they are also manageable at the household level.

3.5 Salient Features of Minor Irrigation Development of the State:

From the preceding discussion it is clear that the irrigation development in the state is mostly undertaken under government sector. However, there is an increasing emphasis on development of minor irrigation over the years owing mainly to the failure of the major and medium irrigation schemes. But it is very interesting to find that development of irrigation under minor irrigation schemes has mostly taken place under the private or individual ownership mainly through construction of well and tubewells. However, the available data given by the State Irrigation Department does not provide enough information regarding pattern of development of minor irrigation schemes in the state. Therefore, following discussion attempts at understanding the salient features of minor irrigation development over the years drawing insights from the Minor Irrigation (MI) Censuses conducted by the Ministry of Water Resources (MoWR), Government of India in different years. The First MI Census (MoWR 1993) was conducted in 1986-87, followed by Second, Third and Fourth Census in 1993-94, 2000-01 and 2006-07 respectively (MoWR 2001, 2005, unpublished). There are five different types of MI structures that MI Census enumerates – dug wells, shallow tubewells, deep tube wells, surface lift systems, and surface flow systems. In all MI Censuses, groundwater structures (dug wells, shallow tubewells, and deep tube wells) have accounted for more than 90 percent of all structures. While an attempt is made to see the development of MI schemes in the state vis-à-vis India, a district level analysis is also made to understand the pattern of groundwater based irrigation development across different districts of the state.

3.5.1 Predominance of Groundwater Structures in MI schemes:

One of the important features of minor irrigation development is that groundwater structures dominate the MI schemes. The share of groundwater and surface water schemes in MI schemes is presented in Table 3.11.

It is evident from Table 3.11 that right from 1986-87, groundwater structures constituted more than 90 percent of all MI schemes in India. The same in Assam constituted more than 70 percent of all MI schemes.

Table 3.11
The Share of Groundwater and Surface Water Schemes in MI Schemes
(1986-87 to 2000-01)

Year	Groundwater Schemes (% to Total MI Schemes)		Surface water Schemes (% to Total MI Schemes)		Total MI Schemes	
	India	Assam	India	Assam	India	Assam
Till 1986-87	90.30	70.59	9.7	29.41	6860370	18397
Till 1993-94	92.50	70.74	7.5	29.26	12466651	39159
Till 2000-01	93.70	88.11	6.3	11.89	19752198	111213
Till 2006-07	94.10	94.19*	5.9	5.81	21004134	110754

Source: Second and Third MI Census (MoWR, 2001, 2005).

* Economic Survey, Govt. of Assam, 2011-12.

Table 3.11 also reveals that while in India the proportion of groundwater structures to total MI structures increased marginally between first and third MI Census, the same in Assam increased marginally from 70.59 percent in 1986-87 to 70.74 percent in 1993-94 and increased sharply to 88.11 percent in 2000-01 and to 94.19 percent in 2006-07. Compared to groundwater structures, the surface irrigation schemes (surface flow and surface lift) declined marginally from 29.41 percent in 1986-87 to 29.26 in 1993-94 and plummeted to 11.89 percent in 2000-01 and 5.81 percent in 2006-07. The sudden spurt in groundwater structures is due to installation of more STWs by the State Agriculture Department through different projects such as ARIASP, ARIDF, AACP, Disaster Management and Technology Mission and AIBP since 1995-96. This clearly indicates an increasing dominance of groundwater structures over the surface irrigation schemes in the country and state respectively.

3.5.2 Number and Growth of Groundwater Structures:

Though groundwater structures constituted the major share in total MI schemes, the number of groundwater structures registered a decline over the Census periods. The number of groundwater structures and its growth between 1986-87 and 2010-11 are presented in Table 3.12.

It is clear from Table 3.12 that while there has been an overall decline in groundwater structures in India over the MI Census periods, the same in Assam has increased largely from 11.40 percent during 1986-87 to 1993-94 to 16.08 percent during 1993-94-2000-

01. The high growth was caused by a large number of installations of STWs in the year 1999-2000. However, the growth rate declined to 2.49 percent during 1993-94 to 2006-07 in the state. In the decade 2000-01 to 2010-11, the state registered the compound annual growth rate of 6.60 percent.

Table 3.12
The Number of Groundwater Structures and its Growth (1986-87 to 2010-11)

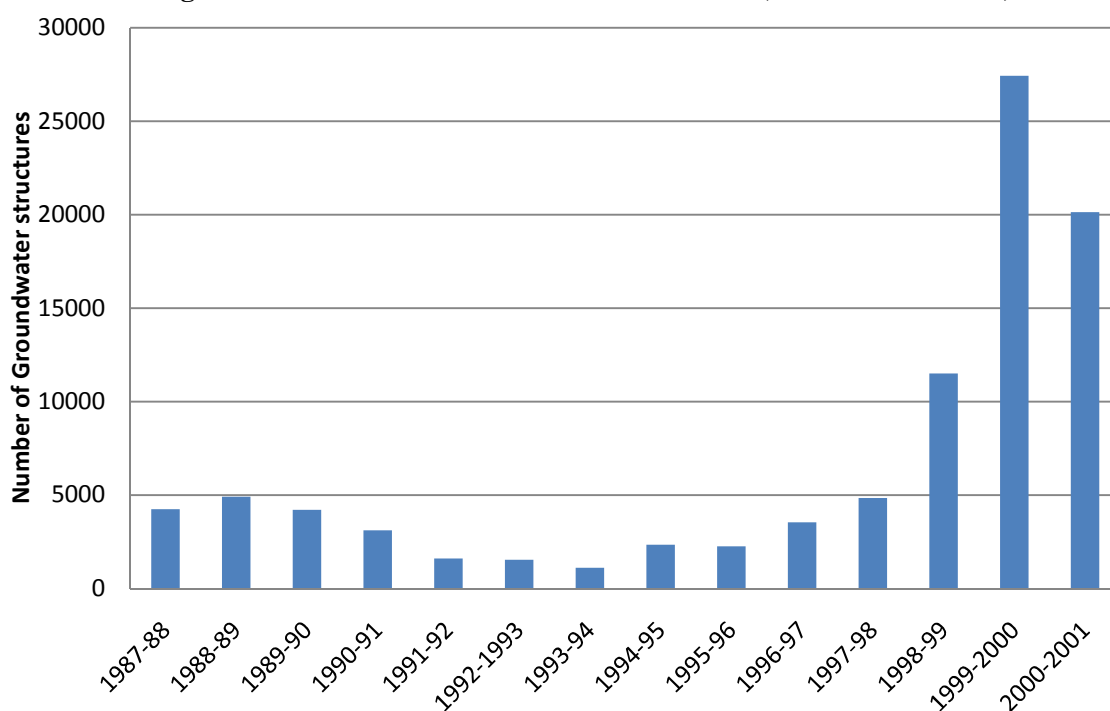
Year	Number of Groundwater schemes	Compound Annual Growth rates (in percent)	
		Assam	India
Till 1986-87	18397	-	-
Till 1993-94	39159	11.40	9.6
Till 2000-01	111213	16.08	6.9
Till 2006-07	110754	2.48	1.1
Till 2010-11*	210756	6.60	NA

Source: Second and Third MI Census (MoWR, 2001).

* Department of Agriculture, Govt. of Assam.

** Pertains to Fourth MI Census (MoWR, 2005).

Figure 3.2: Number of Groundwater Structures (1986-87 to 2000-01)



It is evident from Figure 3.2 that the creation of groundwater structures in the state has not been even across different years during 19987-88 to 2000-2001. The highest number of groundwater structures was created in 1999-2000 followed by 2000-2001 and 1989-99.

As explained above, there are five types of MI structures that the Census enumerates – dug wells, shallow tubewells, deep tube wells, surface lift systems, and surface flow systems. The share of various types of groundwater structures in MI schemes in the state is presented in Table 3.13.

Table 3.13
Composition of Groundwater Structures (1986-87 to 2000-01)

Types of groundwater structures	Up to 1986-87	Up to 1993-94	Up to 2000-01
STW	68.37	69.13	87.29
DW	0.06	0.10	0.15
DTW	2.16	1.51	0.67
SF	8.04	5.99	2.72
SL	21.37	23.26	9.17

Source: Second and Third Census (MoWR, 2001, 2005).

* Department of Agriculture, Govt. of Assam.

** Pertains to Fourth MI Census (unpublished). Data taken from Mukherji et al. (2013).

It is evident from Table 3.13 that in all MI Censuses, groundwater structures have accounted for more than 88 percent of all structures. Out of the total tubewells, the STWs constituted the highest proportion accounting for more than 96 percent of the total tubewells. While STWs constituted 96.85 percent in the total tubewells in 1986-87, it marginally increased to 97.72 percent in 1993-94 then finally to 99.06 percent in 2000-01. Besides, among the groundwater structures, STWs recorded the phenomenal growth outpacing surface irrigation schemes (surface flow and surface lift) in the state over the years. As per data of the 1st, 2nd and 3rd MI Census (the 4th MI Census which was conducted for the year 2006-07, the data has not been officially released) in 1986-87, about 8 percent of the groundwater structures were surface flow. This declined to 5.99 percent in 1993-94, and further to 2.72 percent in 2000-01. Similarly, in 1986-87, while 21.37 percent of the groundwater structures were surface lift, it declined to 23.26 percent in 1993-94, and further to 9.17 percent in 2000-01. Compared to surface flow

and surface lift, the STWs constituted about 68.36 percent of the groundwater structures in 1986-87 which marginally increased to 69.13 percent in 1993-94 and further to 87.29 percent in 2000-2001.

The increasing dominance of groundwater structures in MI schemes in the state also indicates an uneven trend in minor irrigation development across different districts of the state. Among the three geographical regions, the prospect of groundwater irrigation in the hilly region is limited to the small inter-mountain valleys and in Barak Valley region groundwater layer and reserve is generally unsuitable for setting up groundwater based irrigation systems (Dutta, 2011). Therefore, the groundwater based irrigation development has been found concentrated largely in the Brahmaputra Valley region. For example, out of the total wells and tubewells of 79,578, about 99.87 percent of them were constructed in the Brahmaputra valley region in 2000-01 (MoWR, 2005). The same figure stands at 2, 10,756 numbers in 2010, where the Brahmaputra Valley Region shares nearly 99 percent of them (DoA, Govt. of Assam, 2010).

Though there has been a speedy expansion of groundwater structures in Assam, the pump density is still very low compared to the national figure. Since Assam falls in the groundwater abundant region in Eastern India a comparison is also made with the Eastern part of India which comprises of states: Assam, Bihar, Jharkhand, Odisha and West Bengal for a better understanding of the rate of growth of groundwater structures.

Table 3.14

The Number of Wells and Tubewells per 100 Hectare of Net Sown Area (NSA)

Region/Year	1986-87	1993-94	2000-01	2006-07
India	8.34	11.4	14.04	14.13
Eastern India	6.94	9.26	11.48	9.06
Assam	0.48	1.02	2.91	3.79

Source: Second, Third and Fourth MI Census (MoWR, 2001, 2005, unpublished)

Net Sown Area is taken from Economic Survey, Assam, various years.

It is apparent from Table 3.14 that the pump density measured in terms of number of wells and tubewells per 100 hectares of Net Sown Area (NSA) has been increasing since 1986-87 in both India and Assam though Eastern India recorded a decline during 2000-01 to 2006-07. The decline in pump density in Eastern India is due to absolute decline in groundwater structures in Jharkhand, Bihar and West Bengal as noted by

Mukherji et al. (2013). In 2006-07, while per 100 hectares of land 14.13 number of wells and tubewells are available in India, the same is 9.06 in Eastern part and 3.79 number in Assam. If we calculate the same for the Brahmaputra Valley region (which shares about 99 percent of the total groundwater structures in the state), the numbers of wells and tubewells per 100 hectares of land is found to be 3.86 numbers marginally higher compared to total figures for the state.

Thus, the groundwater structures accounted for more than 88 percent of total MI schemes and STWs accounted for about 99 percent of the total groundwater structures in the state. This trend is visible in groundwater sector across the country. For example, in 1986-87, almost 70 percent of the groundwater structures were open dug wells. This declined to 60 percent in 1993-94, and further to 50 percent in 2000-01. Considering this trend in favour of STWs, in the following analysis different aspects of development of STW based irrigation has been discussed in details.

3.5.3 Ownership of Shallow Tubewells:

Regarding ownership of wells and tubewells, if we look at the MI Censuses it is clear that individual farmers with private land, own the bulk of India's wells and tubewells (up to 98 percent in 2000-01). A clear trend of private ownership outstripping government or public ownership has also been noticed over the years. For example, in India in 1993-94, where roughly 80 percent of the deep tube wells were privately-owned, by 2000-01, 90 percent went to private hands. In Assam too, in 1993-94 nearly 88 percent of the tube wells (STWs) were under private/individual ownership while 9 percent of the tube wells were under government ownership. But over the years, public ownership has declined rapidly paving a way for more private ownership. The 3rd MI Census shows that more than 98 percent of the tubewells were owned by private individuals. The share of public ownership of the total wells had declined from 9 percent in 1993-94 to 1.31 percent in 2000-01. A district level analysis also shows that in majority of the districts (except Dhemaji, Goalpara, Lakhimpur and Sibsagar) private ownership outstripped the government ownership. It is clear from Table 3.19 that though all tubewells in Hailakandi district were owned by the government, in six districts (Barpeta, Bongaigaon, Darrang, Karbianglong, Karimganj, and Morigaon) by 2000-01 there were no tubewells under government ownership. It is also apparent from

Table 3.15 that all tubewells (100 percent) in Morigaon and Karbi Anglong districts came under individual ownership by the Census year 2000-01.

Table 3.15
District-wise Percentage of Individual and Government Ownership of Shallow Tubewells in 1993-94 and 2000-01

Sl. No.	Name of District	1993-94		2000-01	
		Individual farmers	Govt. ownership	Individual farmers	Govt. ownership
1	Barpeta	95.30	4.19	99.98	0.00
2	Bongaigaon	96.71	3.05	99.95	0.00
3	Darrang	78.28	14.88	99.93	0.00
4	Dhemaji	89.54	1.12	96.58	3.25
5	Dhubri	95.10	3.62	99.75	0.04
6	Dibrugarh	81.66	18.14	99.93	0.05
7	Goalpara	87.93	7.87	87.84	11.09
8	Golaghat	91.31	8.08	99.91	0.06
9	Hailakandi	0.00	100.00	0.00	100.00
10	Jorhat	71.98	25.84	87.42	12.37
11	Kamrup	68.25	7.49	95.38	0.04
12	Karbianglong	66.67	32.10	100.00	0.00
13	Karimganj	0.00	100.00	75.00	0.00
14	Kokrajhar	97.10	0.00	96.94	0.20
15	Lakhimpur	86.79	13.21	78.22	17.59
16	Morigaon	87.24	12.76	100.00	0.00
17	Nagoan	95.58	4.42	98.71	0.05
18	Nalbari	88.00	10.44	96.25	3.26
19	Sibsagar	99.75	0.13	97.79	2.21
20	Sonitpur	90.62	6.38	98.97	0.07
21	Tinsukia	94.76	4.74	99.30	0.70
State total*		88.16	9.02	97.87	1.31

Note: * No data available for the remaining 2 districts.

Source: Second and Third Census (MoWR, 2001, 2005).

3.5.4 Tubewell Ownership and Size of Land Holding:

Regarding tubewell ownership according to the size of land holding of the owners, the available MI Censuses bring into light two interesting facts: (1) that small and marginal farmers (owning less than 2 hectares of land) own a major share of ground water structures, and (2) this trend of small and marginal farmers owning wells and tubewells has increased over the years. The ownership of tubewells according to the size of land holding of the owners is presented in Table 3.16.

Table 3.16
Ownership of Shallow Tubewells According to the Size of Landholdings
of the Tubewell Owners (in percent)

Year	Marginal (0 - 1 ha)	Small (1 - 2 ha)	Medium (2 - 10 ha)	Big (> 10 h a)
1993-94	2.03	14.71	82.96	0.28
2000-01	37.10	40.96	20.59	1.36

Source: Second and Third Census (MoWR, 2001, 2005).

Table 3.16 shows that the small and marginal farmers together owned 78.06 percent of STWs in Assam in 2000-01 (66.10 percent for India). Comparing this with the data for the year 1993-94, it has been found that while in 1993-94 the small and marginal farmers combined together owned 16.71 percent of the total STWs, the same increased to 78.06 percent in 2000-01. While farmers with medium size of land holdings owned more than 82.96 percent of STWs in 1993-94, the same plummeted to 20.59 percent in 2000-01. However, over the same period the share of big farmers owning STWs increased from 0.28 percent in 1993-94 to 1.36 percent in 2000-01. Thus, the predominance of small and marginal farmers owning STWs clearly obviated one of the popular beliefs that only wealth and large farmers can afford investment on tubewell ownership.

3.5.5 Financing of Wells and Tubewells:

It is clear from the previous section that the small and marginal farmers combined together have owned and operated a lion share of STWs in the state. Therefore, it is important to know how they have financed ownership of the tubewells. Based on the data furnished by the Second and Third MI Censuses, the financing of tubewells by the farmers, can be understood in a clear manner. The sources of funding for the tubewells have been classified under six types: private funding (purely private investment), government funding (purely public funding), only subsidy, subsidy and bank loans, bank loans and savings (combination of private and public funding), and others. Different sources of finance for the construction of tubewells in the state are presented in Table 3.17.

It is clear from Table 3.17 that in the state, subsidy given by government through its different departments accounted for the highest contributing source of finance for tubewells.

Table 3.17
The Sources of Finance for Construction of Tubewells in Assam (1993-94 and 2000-01)

Source of Finance	Number of Groundwater Structures and % to total in 1993-94	Number of Groundwater Structures and % to total in 2000-01
Farmers' savings	08.73 (67.83)*	19.99 (73.2)
Government funds	00.40 (7.3)	04.97 (6.7)
Loan and savings	01.71	05.90
Subsidy and bank loans	22.10	08.89
Subsidy only	66.96	57.06
Other sources	00.09	03.20

* Figures in parentheses refer to all India average.

Source: Second and Third Census (MoWR, 2001, 2005).

However, Table 3.17 shows that during the period 1993-94 to 2000-01, the share of subsidy registered a decline when the share of farmers' private savings increased by more than two folds. However, for the country as a whole, private investment by the farmers is the single most dominant mode of financing unlike the state (Mukherjee et al., 2013).

3.5.6 Intensity of Tubewell Use, Water Distribution System, Water Lifting Devices, Horse Power of the Tubewells:

There are different methods for the distribution of water extracted from a tubewell which include open channel, drip irrigation and sprinkler irrigation. It has been found that water pumped out by the tubewells has been distributed through the open channel (90.28 percent) while drip irrigation system and sprinkler irrigation system (the most effective systems) constituted 2.24 percent and 0.70 percent respectively.

Based on fuel or power used to operate a pumpset, tubewells are classified into two types: diesel operated tubewells and electricity operated tubewells. While, nearly 99 percent of the tubewells in the state are diesel operated in 2000-01, electricity operated tubewells constitute only 0.66 percent. More than 98 percent tubewells are of the capacity in the range of 4 to 6 horse power (hp).

3.5.7 Ultimate Irrigation Potential, Irrigation Potential Created and Irrigation Potential Utilised:

Looking at the ratio of the irrigated potential utilised (IPU) (which shows the gross area that is actually irrigated) to the irrigation potential created (IPC) (which is defined as the total gross area that can be irrigated under different crops during a year by a scheme that has already been constructed) we can have a clear picture of the extent of utilisation of irrigation potential created. Using available data furnished by the 3rd MI Census on IPU and IPC for the state, the ratio is calculated out to be 0.75 indicating that out of the total irrigation potential created by all groundwater structures in 2000-01, 75 percent of them has been utilised. This however plummeted to 51.33 percent in 2006-07 (Govt. of Assam, 2012a). Among the five groundwater structures, the irrigation potential created through Surface Flow has been largely utilised (92.91 percent) followed by STWs whose 80.74 percent of its potential created was utilised. Compared to 1993-94, the state recorded a sharp rise in the utilisation of irrigation potential created which was 45.32 percent of the total irrigation potential created by all groundwater structures. The State Irrigation Department identified a slew of reasons for such a large gap between irrigation potential created and irrigation potential utilised, which include, general wear and tear of the schemes, damage caused by natural calamities like flood, storm, etc., erratic power supply in respect of the electrically operated schemes (Surface Lift and Groundwater Lift), damage of transformer, HT line and mechanical components, change of river course in respect of Surface Flow and Surface Lift Irrigation schemes, damage of canal system, no demand for cultivators, reluctance of cultivators to adopt multiple cropping where assured irrigation is necessary, non-functioning of the schemes due to the of motors/pumps and other accessories, imposition of irrigation services charges by the government for realisation from the cultivators (Govt. of Assam, 2012b).

We can divide all districts in Assam based on IPU to IPC ratio (if this ratio is more than 75 percent, we can say those districts have achieved a high level of realisation of IPU; otherwise it is low). The typology of districts based on percentage of irrigation potential utilised to irrigation potential created (in 2000-01) is presented in Table 3.18. It is clear from Table 3.18 that among the 21 districts (data on remaining two districts are not available) majority of them (61.09 percent) fall in the category where potential utilised is more than 75 percent of the created potential. Districts where utilisation of irrigation

potential created through tubewells have been found to be less; emphasis has to be given for betterment of the same.

Table 3.18
Name of Districts based on Percentage of Irrigation Potential Utilised to
Irrigation Potential Created (in 2000-01)

Classification based on IPU to IPC ratio	Name of districts
High irrigation potential utilised (IPU) to irrigation potential created (IPC) (> 75%): High utilisation districts	Bongaigaon, Dhubri, Dibrugarh, Goalpara, Kamrup, Karbianglong, Kokrajhar, Morigaon, Nagaon, Nalbari, Sibsagar, Sonitpur, Tinsukia (13 districts*)
Low irrigation potential utilised (IPU) to irrigation potential created (IPC) (< 75%): Low utilisation districts	Barpeta, Darrang, Dhemaji, Golaghat, Hailakandi, Jorhat, Karimganj, Lakhimpur (8 districts)

* Data on remaining two villages are not available.
 Source: Second and Third Censuses (MoWR 2005).

3.5.8 Constraints Faced by the Farmers for the Use of Groundwater Structures:

All available MI Censuses provide number of the groundwater structures which are presently not in use. The Second and Third Censuses also provide figures on the potential irrigated area lost as a result of it and give reasons for non-utilisation of the groundwater irrigation. Till 2000-01, in Assam only 75 percent of the potential created by ground water structures have been utilised.

The 3rd MI Census listed inadequate power, mechanical breakdowns, less water discharge, and other unspecified reasons as the constraints faced by the owners of groundwater structures that prevented them from making full use of their wells and tubewells. Regarding utilisation of potential created through STWs the 3rd MI Census listed that about 52.83 percent owners of tubewells faced constraints. Among the types of constraints while about 5.89 percent faced mechanical breakdown of the tubewells, about 1.48 percent faced less water discharge from the tubewells and about 0.77 percent faced the problem of inadequate supply of power. The majority of them i.e. about 44.70 percent cited some other reasons (not explicitly mentioned) as major constraint for lower level of utilisation of the potential created. Among the other

reasons, one reason might be the lower size of farm holding of the owners of tubewells. Therefore, any market arrangement with the neighbouring farmers may facilitate better utilisation of the created potential (Dutta, 2011).

3.6 Summing Up:

It is clear from the above discussion that development of irrigation in the state has resulted in a phenomenal growth of groundwater based minor irrigation schemes in the late nineties of the previous century. Regarding spread of groundwater lift schemes, initially Deep Tube Wells (DTWs) based minor irrigation schemes were developed mostly under government sector. The state government started development of minor irrigation schemes in the private sector only in later part of 1980's with the setting up of ASMIDC in 1980. But there was no significant private investment in minor irrigation schemes until the later part of 1990's. However, two projects, viz. ARIASP funded by the World Bank (started in 1995-96) and SKY under Rural Infrastructure Development Fund (RIDF) of NABARD (started in 1999-2001), have taken headway in the speedy diffusion of shallow tubewells in the state. Under the RIDF, minor irrigation was developed through the distribution of shallow tubewells under private/individual ownership in the state whereas it was under state ownership in other states (NABARD, 2007-08). As of March, 2010, a total of 2, 10,165 number of shallow tubewells and 1, 496 numbers of deep tubewells have been installed in the state. The discussion on various features of minor irrigation development of the state shows that majority of the shallow tubewells (more than 98 percent) have been installed under private or individual ownership.

A few studies on irrigation development of the state have pointed out that some of the owners of shallow tubewells enjoying the advantage of excess capacity (of their tubewells) engage in water transaction with the neighbouring farmers who do not own tubewells (Dutta 2011, 2012). Thus, the proliferation of private tubewell irrigation technology has resulted in ground water transaction in some pockets of the state. The emergence of water markets in the state is expected to facilitate the small and marginal farmers an access to groundwater irrigation. Therefore, it is imperative to know how groundwater is exchanged between farmers of different categories, the market and non-market factors that influence this exchange and other related issues of the market (discussed in chapter one and two in details). Since there is no secondary sources of

data on the operation of groundwater or water markets in the state, carrying out a field work has become important. Accordingly, a detailed field study with individual farm households (participating in groundwater markets) as ultimate units of observation, was carried out in the year 2011-12. The details of the study area, samples, broad profile of the sample and a preliminary analysis of field level data are presented in the next chapter. The subsequent six chapters are based on the findings of the field study.





CHAPTER FOUR

FIELD STUDY LOCATION, SAMPLE AND SAMPLE PROFILE

4.1 The Purpose of Field Study:

The discussions in chapter 3 on the state of groundwater based irrigation development in Assam are based on aggregate data collected from various government and semi-government sources. The pattern of irrigation development in the state clearly shows an increasing dominance of the minor irrigation schemes over the major and medium irrigation schemes. The spurt in minor irrigation development is mainly dominated by the shallow tubewells, especially since the late nineties of the previous century. The STW constitutes about 90 percent of the total groundwater structures in the state. Discussion in chapter three, also has pointed out that more than 98 percent of the STWs have been found to be under private/individual ownership. Previous studies on irrigation development of the state have pointed out that in some areas, the owners of tubewells have been found to be engaged in groundwater transaction with the non-owners (Dutta, 2011, 2012). Thus, groundwater market as an institution has emerged in some pockets of the state, facilitating the use of groundwater for irrigation to the small and marginal farmers in the neighbourhood of the tubewells. But understanding how groundwater is exchanged between farmers who participate in the market under different farm size categories and the market and non-market factors that influence this exchange is not possible without looking at the structure and operation of the groundwater market in details. Further whether use of groundwater irrigation has been beneficial to the farmers or not cannot be addressed without looking at efficiency of groundwater use or technical efficiency of the farmers using groundwater as the main input at the farm levels. This institutional arrangement that erupted in agricultural practices of many states in the south Asian Countries is quite informal and transaction mostly takes place at the will of the sellers. Therefore, in the process, the market arrangement may be highly unreliable for the buyers in terms of availability of adequate water for irrigation at the time of requirement of the buyers. These pertinent issues, call for a detailed study on groundwater use in agriculture in the state, where market as an institution facilitates use and spread of access to groundwater among resource poor farmers. To obtain specific answers to the questions posed for this study, data on the agricultural production using groundwater irrigation and functioning of

groundwater markets were needed. Accordingly, a field survey was carried out in the agricultural year 2011-12 at a few selected pockets of the state where groundwater market has been found.

The aim of field study was to examine the nature, structure and functioning of the groundwater market, to identify determinants of tubewell ownership, water buying and selling decisions of a farmer, to identify determinants of reliability of the market in supplying adequate water at the time of requirement and to estimate technical efficiency scores on farmer's plots.

4.2 Selection of Area for Field Study:

The study is confined to summer rice only. The crop is cultivated in the dry season from November to May in low lying areas of the state. Since the cultivation of the crop is mainly based on groundwater based-irrigation, the farmers without own tubewell rely on market for water (Dutta, 2011, 2012).

The field study locations were selected from the Brahmaputra Valley which constitutes about 72 percent of the total geographical area and about 92 percent of population in the state. The other two geographical divisions namely, the Barak Valley and the Hills were completely left out from the study as irrigation potential developed in these areas is still very limited and the area grown under summer rice where groundwater market transaction is found to be prevalent, is also remarkably low (Dutta, 2011; Govt. of Assam, 2012b). The selection of the Brahmaputra Valley is also guided by the fact that the valley constitutes more than 99 percent of the STWs installed in the state since 1980 till 2010 (MoWR, 2005; DoA, Govt. of Assam, 2011). Among the four Brahmaputra Valley Agricultural Zones, (viz., the North Bank Plain, the Upper Brahmaputra Valley, the Central Brahmaputra Valley and the Lower Brahmaputra Valley) the Central Brahmaputra Valley Agricultural Zone comprising of two districts, viz. namely Nagaon and Morigaon districts, was selected for the study. The selection of the districts is guided by the fact that these districts have better concentration of groundwater market activities in the cultivation of summer rice especially in the low lying pockets of the districts. It has been found that the market practice exists in many parts of the districts. However, the incidence and variability is relatively high in a few locations. While almost all parts of Morigaon district is characterised by this

groundwater market practice, in Nagaon district the markets concentrate only in a few places. Wherever the market operation takes place, the activities are found to be very intensive. It is found that Nagaon and Morigaon districts represent the area in which cultivation of summer rice is growing faster than the other districts in the state (Talukdar, 2005). Together, these two districts account for about 37 percent of the total area under summer rice cultivation in the state (Govt. of Assam, 2013a).

4.3 Sample:

From the two districts, sample villages were randomly selected from the areas characterised by the presence of the market for groundwater. Due care was taken so that sample villages are not close to one another. The reason for doing this is to capture differences in the operation of the market activities by selecting villages from different places. Moreover, while selecting the sample attention was given to select as many villages as possible as the repeated pilot survey by the researcher shows that the functioning of market for groundwater among the farmers in a village has been found to be similar. Sample farmers are those who cultivate summer rice with an access to groundwater irrigation. Since the primary objective of the study is to examine the issues of groundwater market, sample farmers are basically those who participate in groundwater transaction either as buyers or sellers of water. Buyers are usually the non-owners of tubewells though a few owners might also be the buyers of water on fragmented plots. STW owners were those who have installed at least one tubewell, either diesel operated pumpset or electricity operated pumpset or the both, for irrigation. Since our primary focus is to capture the market activities and an owner of tubewell may not be engaged in water selling, while drawing sample attention was given to select owner-cum-sellers. However, a few owners of tubewell though found to be not engaged in water selling, have been selected as control group to see the difference in the attainment of technical efficiency of farmers with or without their participation in water market. From each village, finally about 10 to 15 percent of the irrigated farm households were selected at random as the ultimate sample units for detailed investigation. Accordingly, 198 farm households selected in this manner from the selected villages, constituted the whole sample of the field study.

Data were collected on various aspects which are: tube-well-specific, production specific, household specific and market-specific. Due emphasis was given on the

following aspects: (i) general information about the farm family, including family size, family type, education level of the household head, size of the land holdings, sources of non-farm income, etc.; (ii) information regarding sources of irrigation, details of tubewell characteristics, investment on tubewells, operational and maintenance costs of running a pumpset, extent of mechanisation of the farms, costs and returns of crops grown, total production, cropping pattern, etc. and (iii) information regarding existence of water markets and their types, functioning and prevailing pricing system, particulars of water purchase and sale, reasons for buying and selling of water, exiting social capital enjoyed by the farmers, property rights governing the water use, etc.

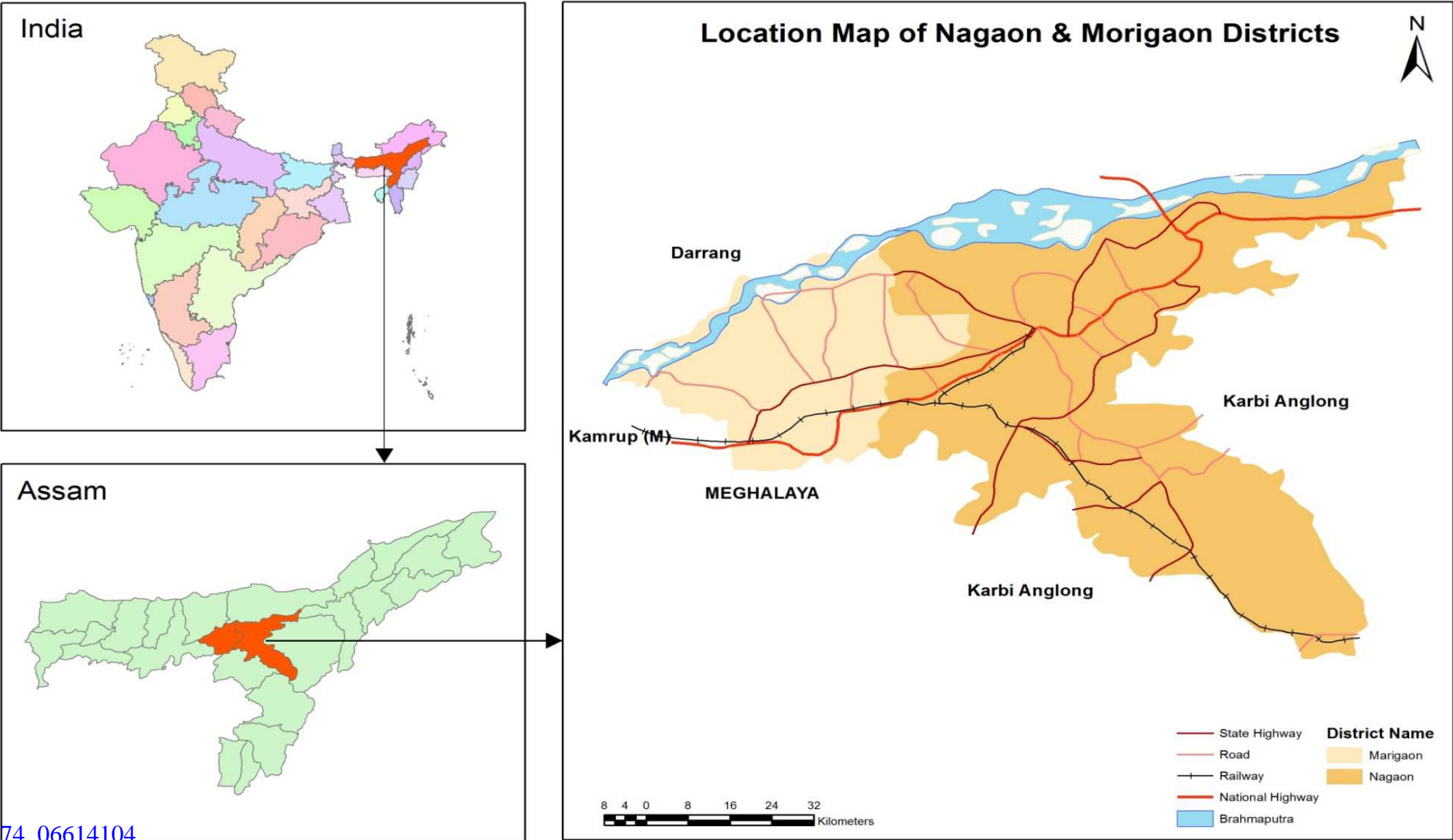
A standard and systematically designed semi-structured interview schedule was administered in the field for the purpose of eliciting detailed information from the respondents. The interview schedule was prepared in consultation with the supervisor of the study and finalised after a number of pilot surveys. Focus Group Discussion (FGD) with a few selected respondents was conducted to collect qualitative information relating to various aspects of the groundwater market. The interview schedule used to collect data is appended at the end of the dissertation (Appendix - 4.1). Field work was carried out during the crop year 2011-2012. Thus, the survey data elicited from the respondents pertain to the year 2011-2012.

Presentation and analysis of the data collected in the field survey have been laid out over the next four chapters including the present chapter.

4.4 Broad Profile of the Sample Districts:

As discussed above, two districts, viz. Nagaon and Morigaon from the Central Brahmaputra Valley Zone (CBVZ) have been selected for the field study. In this section a brief profile of the two districts focusing basically on the state of the economy of the districts has been presented. The location map of the districts is shown in Map-1.

Map -1: Location Map of Nagaon and Morigaon Districts





4.4.1 Nagaon District:

Nagaon district is situated between 25° 45' to 26° 45' North Latitudes. On the north, Nagaon is bound by Sonitpur district and the river Brahmaputra, towards its south lies Karbi Anglong and North Cachar Hills, towards its east lies the districts of Karbi Anglong and Golaghat. The area of the district spans 3, 993 km² making it one of the largest districts of Assam. As per Population Census 2011, there are 10 Revenue Circles, 18 Community Development Blocks, 239 Gaon Panchayats, 1, 412 Villages in the district. The administrative headquarter of the district is located at Nagaon town.

According to Population Census 2011, Nagaon district has 28, 26, 006 population. During the period 2001-2011, the population of the district recorded a growth rate of 22.09 percent, whereas the population for the same period in the state increased by 16.93 percent. Like other districts of the state, Nagaon too has a higher proportion of people residing in rural areas than those in urban areas. According to Census 2011, the population in the rural areas in Nagaon district is about 24, 57, 906 accounting for 86.97 percent of the total population of the district. The district with about 5.07 percent area of the state accommodates about 9.07 percent of the state's total population as per Census 2011. The density of population per square kilometer in the district is 719 persons as against 397 persons for the state as a whole. The sex ratio of Nagaon district is 962 females per thousand males as against 954 for the state as a whole. The literacy rate of Nagaon is 73.78 percent against 73.28 percent for Assam as a whole. The male literacy rate in Nagaon district is 78.19 percent and for female 67.27 percent against 78.81 and 67.27 percent for male and female literacy rate respectively for Assam as a whole.

The total work force of the district consists of 7, 27, 641 persons in 2001, representing about 25.75 percent of total population of the district as per 2001 Census. The male and the female work force participation rate in the district accounts for about 80.62 percent and about 19.37 percent respectively. Cultivators and agricultural labourers together account for 58.28 percent of the total work force of the district showing predominance of agriculture as the main source of livelihood.

Agriculture is considered to be the most important sector in the economy of the district engaging about 58.28 percent of the total working population. Of the total work force of the district, about 31 percent are cultivators and about 12 percent are agricultural labourers (Census 2001). The total number of farm families in the district is 2, 11,346 (7.68 percent of the total farm families of the state) as per Agriculture Census 2005-2006. Out of the total reporting area, the Net Sown Area (NSA) covers about 57.32 percent of the total geographical area of the district. The production of food grains occupies the foremost place in the district. Rice, wheat and maize are the main staple food grains, which are produced in the district. Rice, the main staple food crop of the district occupies about 56 percent of the net sown areas in 2010-11, while the rest of the areas is mainly devoted to produce wheat, maize, jute, sugarcane, potato, blackgram, pea, lentil, rape and mustard, etc. The cropping intensity of the district is 124 percent while the same for the state is 146 percent (Govt. of Assam, 2012a). The total area under summer rice in the district was 63.73 hectares which is 26.51 percent of the total area under three different varieties of rice in the district in 2010-11. The area under High Yield Variety (HYV) summer paddy in the district was 41.43 percent of the total area under three categories of paddy grown in the district in 2006-07 (Govt. of Assam, 2007a). The contribution of agricultural sector to Gross District Domestic Product at current price in 2009-10 is estimated to be about 30.16 percent.

Regarding the status of irrigation development of the district as of 2010-2011, a total area of 10, 3, 930 hectares of irrigation potential was created which was 16.04 percent of the total irrigation potential created in the state. Out of the total irrigation potential created 18, 088 hectares (17.40 percent) was created under different minor irrigation schemes (Govt. of Assam, 2012a). However, during 2010-11, 1, 325 hectares of additional irrigation potential was created in the district under the minor irrigation schemes. Data for the year 2010-11 on crop-season wise area irrigated revealed that a total of 29, 962 hectares were irrigated, in which *Rabi* and *Pre-kharif* crop season constituted about 17.18 percent. The Net Area Irrigated (NIA) of the district was 24, 812 hectares in 2010-2011 (Govt. of Assam, 2013a). Till June 2010. 23, 482 numbers

of STWs and 602 numbers of LLPs have been installed in the district. Out of the total numbers of STWs, about 98 percent are under private ownership.

The district is enriched with vastness of surface and ground water. The major rivers that flow in the district are the Brahmaputra, Kalong, Sonai, Nanoi, Jamuna, Kopili and the Barpan. Regarding groundwater availability, according to the estimate of CGWB, the district has 14.79 bcm of groundwater reserves which is about 5.43 percent of the total available groundwater reserves of the state. Out of the total available groundwater, about 90 percent are available annually for drafting. About 44.89 percent has been annually drafted for irrigation purpose. The district is still left with ample groundwater reserves for development of irrigation.

4.4.2 Morigaon District:

Morigaon district is situated between 26.15° to 26.5° North latitude and between 92° East longitudes. It is situated on the south bank of the river Brahmaputra. Nagaon district is situated on its East, Darrang on the North, Kamrup Metro on the West and South West Karbi Anglong on its south. The total area of Morigaon district is 1551km² which is the second smallest district of Assam. It has three urban areas: Morigaon, Jagiroad and Jagiroad paper mill covering an area of 17.92 km². The mighty Brahmaputra flows along with the northern boundary of the district. Killing, Kollong and Kapili rivers flow through the southern part of the district. Administratively, Morigaon has one sub-division namely Morigaon. Presently, the district has five revenue circles namely Morigaon Sadar, Mikirbheta, Laharighat, Bhuragaon and Mayong and five Community Development Blocks (CDB), viz. Mayaong, Kapili, Bhurbandha Laharighat and Moirabari. The total number of revenue villages in the district is 636 and there are 85 Gaon Panchayats under five CDBs. The administrative headquarter of the district is located at Morigaon town.

According to the Population Census 2011, Morigaon district has 95, 7, 853 population. During the period 2001-2011, the population of the district recorded a growth rate of 23.39 percent whereas the population growth rate for the state was 16.93 percent. Like other districts of the state, Morigaon too has a higher proportion of people residing in rural areas than those in urban areas. According to 2011 Census, the population in the

rural areas in Morigaon district is about 8, 84,557 accounting for 92.35 percent of the total population of the district. This shows that the rate of urbanisation of the district is very low. The district with 1.97 percent area of the state accommodates about 3.07 percent of the State's total population as per 2011 Census. The density of population per square kilometer in the district is 618 persons as against 397 persons for the state as a whole. The sex ratio of Morigaon district is 974 females per thousand males as against 954 for the state as a whole. The literacy rate of the district is 69.37 percent against 73.28 percent for Assam as a whole. The male literacy rate in Morigaon district is about 73.66 percent and the female literacy rate is 64.99 percent against 78.81 percent and 67.27 percent for male and female literacy rates respectively for Assam as a whole. In respect of human development, as per the Assam Human Development Report (AHDR), 2003, Morigaon ranks fourth in the Human Development Index (HDI) with HDI value of 0.494 against the HDI value of 0.407 for the state as a whole.

The total workforce of Morigaon district consists of 72, 7, 641 persons in 2001, representing about 33.93 percent of the total population of the district as per 2001 Census. The urban work participation rate is about 34.01 percent while the same for rural areas is about 32.37 percent. The male and the female work force participation rate in the district accounts for about 80.62 percent and about 19.37 percent respectively. Cultivators and agricultural labourers together account for about 58.28 percent of the total work force of the district showing predominance of agriculture as the main source of livelihood.

The economy of Morigaon is primarily agrarian and rural with low rate of urbanisation. The industrial scenario of the district is also poor with the total number of registered Small Scale Industrial (SSI) units of 398 which are lowest among all the districts of the state. Of the total work force of the district, about 42.09 percent are cultivators and about 11 percent are agricultural labourers (Census 2001). The contribution of agriculture to the Gross District Domestic Product (GDDP) is estimated to be about 26.26 percent in 2009-10 (at the current price, Govt. of Assam, 2013a). The Net Area Sown is 81, 092 hectares which is about 52.28 percent of the total geographical area of the district. The cropping intensity of the district is 207.52 percent. The average land holding is 0.63 hectare only against 1.10 hectare for the state (Govt. of Assam, 2013a). Total number of farms households of the district is 1, 07,296 as per Agriculture Census

2005-2006. Paddy, Wheat, Jute, Mustard and Vegetables are the major crops grown in the district. Banana, Assam Lemon, Arecanut and Coconut are the other horticultural crops grown in the district. Total area under paddy is 67,869 hectares out of which area under summer rice constituted 54.14 percent in 2006-07. Among the three different types of paddy grown in the district, the area under HYV summer paddy/rice is the highest which is 64.03 percent of the total area under paddy in 2006-07 (Govt. of Assam, 2008a). The cropping intensity of the district is 132 percent against 146 percent of the state.

Although the annual average rainfall is around 2,296.60 mm, most of the precipitation is concentrated between June and September with intermittent dry spell. As a result irrigation becomes a vital need for raising both *kharif* and *rabi* crops. The District of Morigaon has good potential for exploration of surface source as well as ground water resource. The district is drained by a number of perennial rivers and streams. The surface sources which can be utilised are Kapili, Kallong, Kiling, Sonai and Pakaria river and Sonduba, Kachadhara, Lali, Charan Beel of the district. Regarding availability of groundwater reserves, the estimate of CGWB shows that the district has 5.43 bcm of annual replenishable groundwater reserves out of which about 89.99 percent are available to be drafted annually. The state of groundwater development in the district has been 49 percent. Out of the total annual draft of 2.5 bcm, about 93.29 percent have been used for irrigation. The district is also left with ample potential for using groundwater for future use in irrigation.

Morigaon Division (Irrigation) Morigaon has taken up several irrigation schemes in addition to some completed schemes received on transfer from Nagaon Division (Irrigation) Nagaon and Guwahati Division (Irrigation) Guwahati. At present Morigaon Division (Irrigation) has 36 numbers of completed irrigation schemes and 27 number of on-going schemes (i.e. out of 27 numbers ongoing irrigation scheme 17 number of schemes are taken up for improvement of existing schemes). The total potential created in Morigaon district by this Morigaon Division (Irrigation) as on 31-3-2001 is 10,061 hectare in terms of Net Irrigated Area. As on 31-03-2004, the total irrigation potential created under minor irrigation schemes in the district is 17044 hectares (Govt. of Assam, 2009a). Owing to the failure on the part of government's irrigation schemes, recently farmers have resorted to shallow tubewell under private ownership. As of

2010, there are 11, 103 number of Shallow Tubewells and 334 numbers of Low lift Pumpsets in the district (DoA, Govt. of Assam). As per the State Report on Agricultural Census, 2005-06, the NIA of the district is 1128.70 hectares of which about 34.29 percent is served by tubewells.

4.5 Composition of the Sample:

In the field survey conducted in different pockets of the two districts of Morigaon and Nagaon, a total of 198 farmers selected were interviewed. The sample includes 125 farm households from Morigaon district and 73 farm households from Nagaon district. The samples from Morigaon district have been randomly selected from 21 villages from three Community Development Blocks (CDBs), viz. Mayang, Kapili and Laharighat. While Mayang comprises about 48.80 percent of the total sample farms, Kapili and Laharighat account for the rest 51.20 percent. The details of sample farms of the district are presented in Table 4.1.

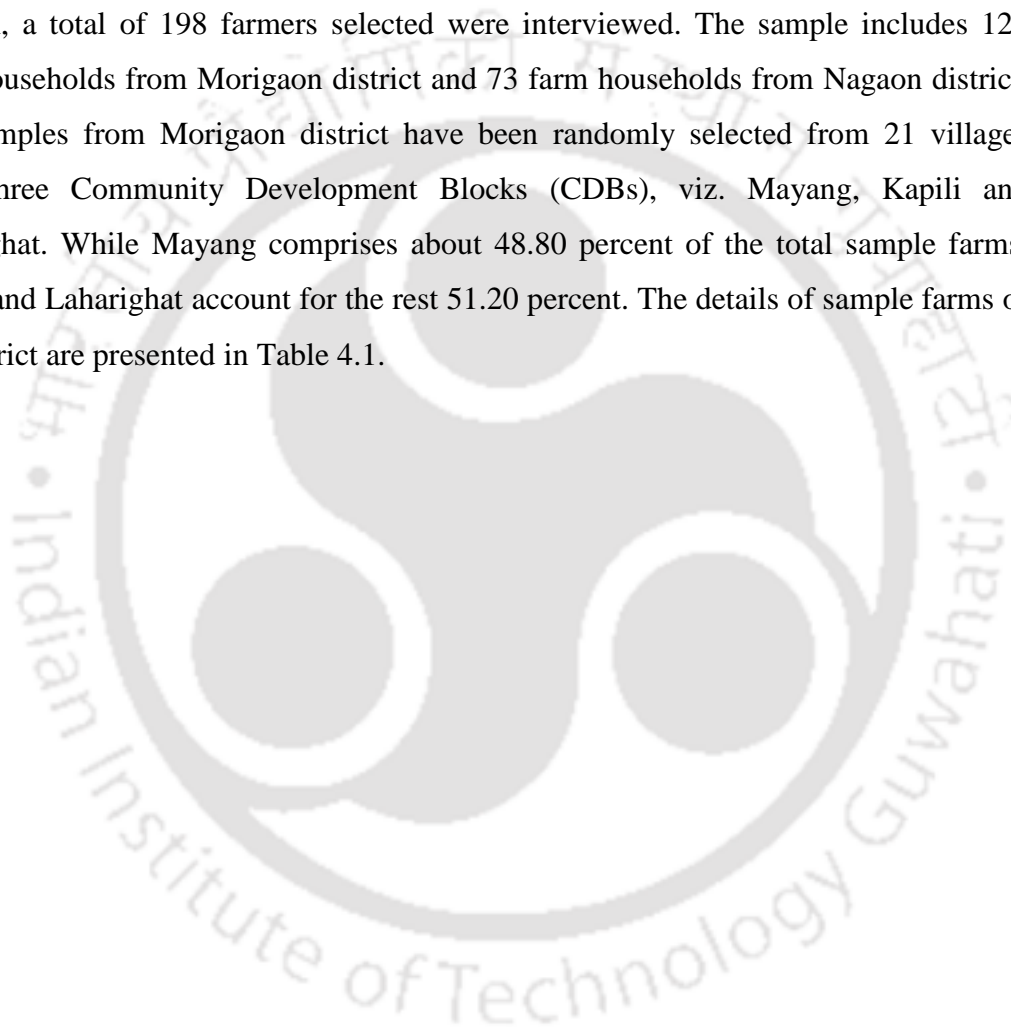


Table 4.1
Survey Locations with Number of Sample Farms in
Morigaon District

Name of the Village	Total
A. Kapili CDB	
Barbhagia	5 (4.00)
Na-Khandia (Satgaon)	3 (2.40)
Na-khandia(Bechaparti)	2(1.60)
Pub-Barbhagia	12(9.60)
Satgaon	6(4.80)
Satgaon (Bengali Chuk)	4 (3.20)
Total	32 (25.60)
B. Laharighat CDB	
Boribandha	5 (4.00)
Garukhuti	6 (4.80)
Jalakiabori	13 (10.40)
Lalaibori	3 (2.40)
Palahajuri	5(4.00)
Total	32 (25.60)
C. Mayang CDB	
Burha buri	2 (1.60)
Burha buri (kusumpur)	3 (2.40)
Gagalmari	5 (4.00)
Garjan	6 (4.80)
Garmari	6 (4.80)
Kacharijan	9 (7.20)
Khalabayan Gaon	5(4.00)
Kuranibori	5 (4.00)
Morisutipam	2(1.60)
Nekerahabi	3 (2.40)
Raja Mayong	15(12.00)
Total	61 (48.80)
Total (A+B+C)	125 (100)

Note: Figures in parentheses represent percentage of the total sample.

The 73 farm households of Nagaon district have been randomly selected from 11 villages from two CDBs, viz. Kapili Pt. and Raha. While about 71.23 percent of the total sample farms in Nagaon district are from Kapili Pt. CDB, about 28.77 percent are

from Raha CDB. The details of villages and the number of sample farms of the district are presented in Table 4.2.

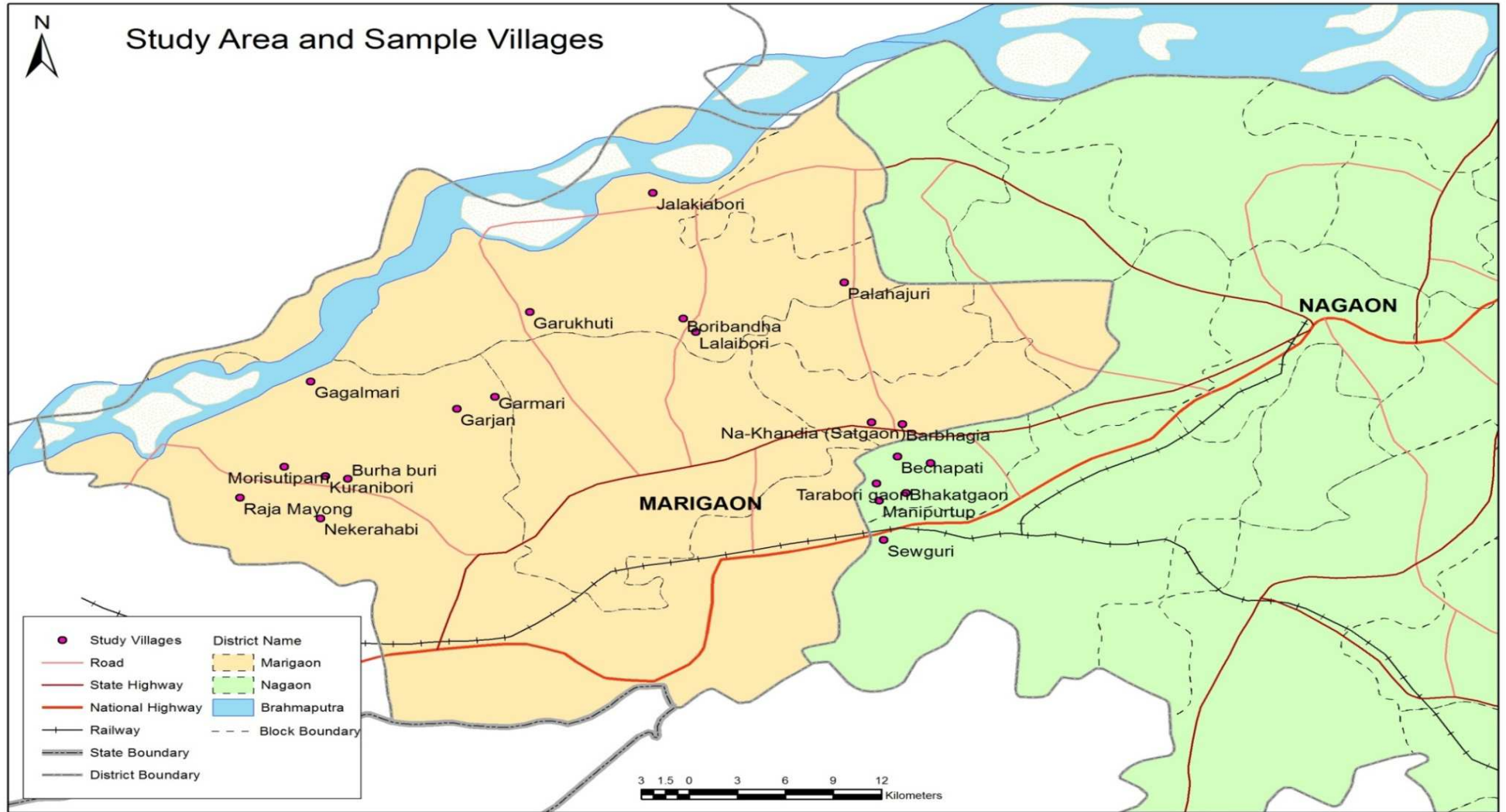
Table 4.2
Survey Locations with Number of Sample Farms in Nagaon District

Name of the Village	Total
A. Kapili Pt. CDB	
Bechapati	2 (2.74)
Bhakatgaon	10 (13.70)
Bhakatgaon (singimari)	5 (6.85)
Borghat	7 (9.59)
Chatarbori	5 (6.85)
Manipurtup	7(9.59)
Nabhanga gaon (Chulapara)	14 (19.18)
Tarabori gaon	2(2.74)
Total	52 (71.23)
B. Raha CDB	
Nambasti	3 (4.11)
Gaspara	3 (4.11)
Sewguri	15 (20.55)
Total	21 (28.76)
Total (A + B)	73 (100)

Note: Figures in parentheses represent percentage of the total sample.

The location of the sample villages is shown in Map-2.

Map-2: Study Area and Sample Villages



Note: Sample Villages are located based on Census Administrative Atlas, 2011. The sample revenue villages have not been shown in the map



4.6 Sample Profile and their Socio-economic Characteristics:

In this section an attempt has been made to analyse the socio-economic composition of the samples.

4.6.1 Caste and Religious Profile of the Sample Farmers:

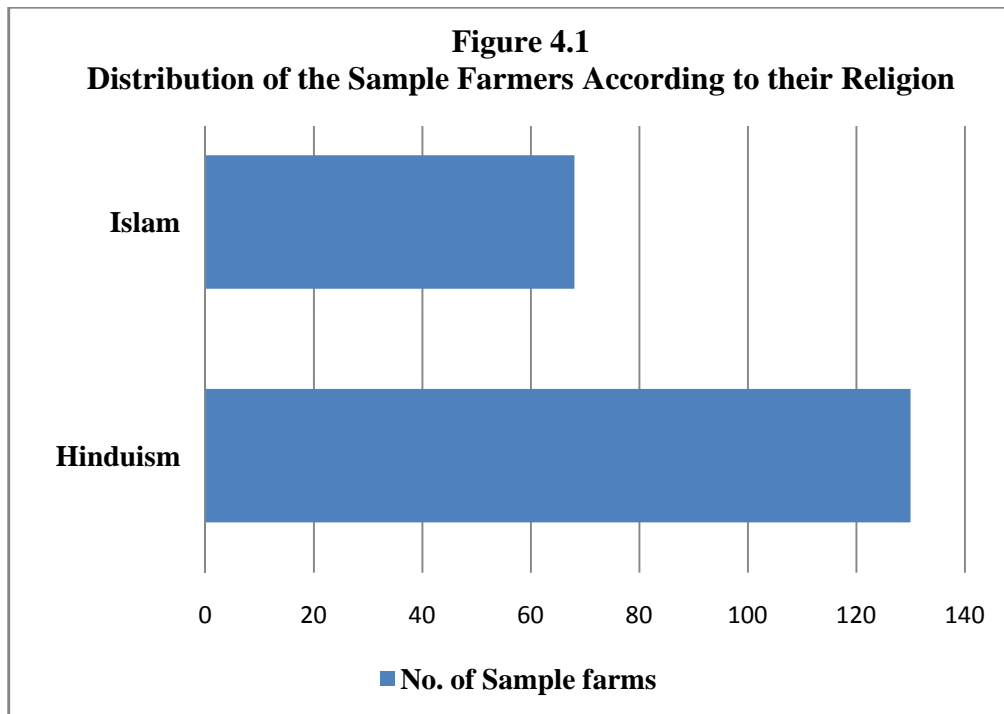
Table 4.3 shows that about 39.9 percent of the farmers belong to general category. While about 36.30 percent belong to Other Backward Caste (OBC), about 12.60 percent belong to Scheduled Tribes (Plain) and about 11.10 percent belong to Scheduled Caste (SC). In the Scheduled Tribes (Plain) category about 50 percent are from Bodo community, about 36.36 percent are from Karbi Community and the rest about 13.64 percent are from Tiwa community.

Table 4.3
Distribution of Sample Farmers According to Caste

Caste	No of sample farms
General	79 (39.9)
Other Backward Caste (OBC_CL)	25 (12.6)
Other Backward Class(OBC_NCL)	47(23.7)
Scheduled Caste (SC)	22 (11.1)
Scheduled Tribes (P)	25 (12.6)
Total	198 (100)

Note: Figures in parentheses indicate percentages of the column total.

Regarding religious composition of the sample farms, it has been found that about 65.70 percent are Hindus whereas the rest 34.30 percent belong to Islam. The distribution of sample farm households according to their religion is shown in Figure 4.1.



4.6.2 Family Size:

Analysis of inputs recorded in the field study relating to family size of the sample farm households shows that the average size of a family is 6.49 with a minimum family size of 2 numbers and a maximum of 17 numbers. Almost all families are found to be nuclear. Only about 1.51 percent of the total sample farm households have joint family.

4.6.3 Educational Profile of the Sample Farmers:

Details of educational profile of the sample farmers are shown in Table 4.4. It is evident from Table 4.4 that about 37.90 percent of the sample farmers are illiterate. More than three fourth of the total literate farmers constituting about 77.23 percent have received education between primary and High School Leaving Certificate (HSLC) levels. About 12.6 percent of the farmers have passed the HSLC examination but remained below Higher Secondary (HS) level. Farmers having higher education (graduation and above) constitute only about 3.5 percent of the total samples. Thus, majority of the sample farmers have attained lower level of education in terms of last class attended by them. On an average, the sample farmers have been found to have completed fifth standard only which is considered to be lower.

Table 4.4
Distribution of the Sample Farmers According to their Level of Education

Educational background	No. of sample farms
Illiterate	75 (37.9)
Primary (up to class five)	20 (10.1)
Primary passed but below HSLC	70 (35.4)
HSLC passed but below HS	25 (12.6)
HS passed but under graduate	1(0.5)
Graduation	7 (3.5)
Total	198 (100)

Note: Figures in parentheses indicate percentage of column total.

4.6.4 Age Profile of the Sample Farmers:

The age profile of farmers has been presented in Table 4.5. The minimum age of the sample farmer has been found to be 22 years while the maximum is 77 years. Figures presented in Table 4.5 indicate that out of 198 farmers, about 7.10 percent belong to the age group below 30 years, about 25.80 percent to the age group 30-40 years and about 26.30 percent to the age group 40-50 years. While about 27.80 percent are in the age group of 50 to 60 years and the rest 13.10 percent farmers belong to the age group 60 years and above. Thus, the highest concentration of farmers is found to be in the age group of 30 to 60 years (93.00 percent) and the lowest concentration is in the age group of below 30 years and above 60 years. It indicates that most of the farmers are in the working age group.

Table 4.5
Distribution of the Sample Farmers According to their Age

Age group of farmers	Nos. of sample farms
Below 30 years	14 (7.10)
30 to 40 years	51 (25.80)
40 - 50 years	52 (26.30)
50 – 60	55 (27.80)
Above 60 years	26 (13.10)
Total	198 (100)

Notes: Figures in parentheses represent percentages of column total.

4.6.5 Occupational Profile of the Sample Farmers:

The distribution of sample farmers according to their occupation has been presented in Table 4.6. It has been found from the field study that about 94.90 percent of the farmers have taken up cultivation as the main occupation of the family. Only 6 farmers out of 198 sample farmers (about 3.03 percent) have non-farm activities as the main source of income, cultivation being the subsidiary source of income. Four out of the total sample farmers have taken up other activities like duckery, fishing and grocery as subsidiary occupation to compensate for the risks involved in cultivation and to enhance their income.

Table 4.6
Distribution of Sample Farmers According to their Main Occupation

Types of occupation	Nos. of sample farmers
Cultivation	188 (94.9)
Cultivation & Duckery	1 (0.5)
Cultivation and fishing	2 (1.0)
Cultivation and Grocery	1(0.5)
Service	2(1.0)
Teaching	4 (2.0)
Total	198 (100)

Note: Figures in parentheses indicate percentages of column total.

However, it has also been found in the field that in a few farm households one or two members of the family are engaged in off-farm activity generating subsidiary income to the family. It has been found that about 46.60 percent of the family has subsidiary income generated by at least one member of the family other than the main farmer. The sources of off-farm income include services like *agwanwadi* workers, carpentry within the locality and security guard services outside the state. It has been reported by majority of the respondents that the availability of off-farm income in the family has helped them to meet operational expenses of farming.

4.6.6 Housing Condition and Availability of Electricity Connection:

Inputs collected from the field study reveal that majority of the farm households have *kutchha* houses (64.10 percent) while about 23.10 percent have *semi-pucca* houses and the rest 12.60 percent have *pucca* houses. Farmers who reside in *kutchha* houses are mostly the small and marginal farmers. Generally, crop fields are attached to the houses of the farmers. However, some crop fields are located 1 to 5 km away from the house. As many as 147 (74.20 percent) farm households have electricity connections out of which 141 (95.9 percent) farms have domestic connections and only 6 (4.1 percent) have commercial connections. The farm households with commercial electricity connections have been found to own rice mills. The fact that a few farm households do not have electricity connections of either type and majority of them have domestic connections have serious implications for the operation of the water market, which will be taken up for detailed analysis in the next chapter.

4.6.7 Availability of Other Infrastructure:

There is no any cold storage facility (either private or co-operative) in any of the sample villages. The minimum distance from the nearby cold storage facility located in Nagaon district, is found to be about a 120 km away from the sample villages of both the districts. The minimum distance from nearby commercial bank branch is 100 meter the maximum being 10 km implying farmers having easy access to the banks. The retail outlets for agricultural inputs like fertiliser and diesel are available in the village *haat* in about 90 percent of the villages surveyed. It has been reported by the farmers that the availability of retail outlet for diesel in the sample villages has been more advantageous to them. It helps them to meet their higher requirement of diesel during peak demand

periods. None of the village is endowed with organised marketing facility for procurement of the agricultural produce. As reported by the sample farmers, the lack of organised marketing facility is one of the major constraints on commercialisation of agriculture.

4.6.8 Access to Information:

Regarding access to information and communication facilities almost all the sample farmers have at least one mobile phone connection though many of them have radio (24.70 percent), television (33.3 percent) and computer without internet facility (8.6 percent) as well.

4.7 Sample Profile and their Agrarian Structure:

In the following sections an attempt has been made to analyse the composition of the samples and their agrarian structure like size of operational holding, incidence of tenancy among the sample farmers, participation of the sample farmers in groundwater transaction, etc.

4.7.1 Farm Size: Total Agricultural Land Holding:

The distribution of the sample farms according to the size of their own agricultural land holding and operational holding are shown in Tables 4.7 and 4.8 respectively.

Table 4.7
Distribution of Sample Farms According to the Size of their Own Agricultural Holding

Size classes of own agricultural holding (in hectare)	Nos. of sample farms
Marginal (below 1.00 hectare)	111 (56.10)
Small (1.00 – 2.00 hectares)	44 (22.20)
Semi-medium (2.00 – 4.00 hectares)	30 (15.20)
Medium (4.00 – 10.00 hectares)	12 (6.10)
Large (more than 10.00 hectare)	1 (0.50)
Total	198 (100)

Note: Figures in parentheses represent percentages of column total.

Table 4.7 shows that in terms of their own agricultural land holding, the maximum concentration of sample farms is in the size category of below one hectare (marginal

farmers) which accounts for about 56.10 percent of the sample farms. This is followed by the size category of 1.00 to 2.00 hectares contributing about 22.20 percent of the total sample farms. These two categories of farmer together account for about 78.28 percent of the sample farms. This signifies the established proposition about the operation of water market that the participants of the market belongs mainly to the small and marginal farmers. However, whether these marginal and small farmers appear as buyers or sellers in the market is examined in the next chapter. Farmers under semi-medium category are 30 which are about 15.20 percent of the total sample farms. About 6.10 percent of the total sample farms are under medium farm size category. Only one farmer has own agricultural land holding more than 10.0 hectares (which is about 0.50 percent of the total sample farms).

Though the discussions on the size of own agricultural land holding are important to look at the incidence of market practices among the farmers, their operational holdings seem to be different as most of them have land on lease. Therefore, it is pertinent to look at their size of operational holdings. The distribution of the sample farms according to the size of their operational holdings is presented in Table 4.8.

Table 4.8
Distribution of Sample Farms According to the Size of their Operational Holdings

Size classes of operational holdings (in hectare)	No. of sample farms
Marginal (below 1.00 hectare)	88 (44.40)
Small (1.00 – 2.00 hectares)	65 (32.80)
Semi-medium (2.00 – 4.00 hectares)	39 (19.70)
Medium (4.00 – 10.00 hectares)	6 (3.00)
Total	198 (100)

Note: Figures in parentheses indicate percentages of column total.

It is clear from Table 4.8 that the maximum concentration of sample farms is in the size category of below one hectare which accounts for about 44.40 percent of the total farms. This is followed by the size category of 1.00 to 2.00 hectares which constitutes about 32.80 percent the total sample farms. Altogether these size groups account for about 77.27 percent of the total operational holdings under the samples. Farmers under semi-medium category are 19.70 percent of the total sample farms. Only 6 farmers

have agricultural holdings between 4.0 to 10.0 hectares which is about 3.00 percent of the total agricultural land holdings. Thus, the proportion of marginal farms in the sample is fairly large.

4.7.2 Total Cultivated Area under Summer Rice:

As clearly indicated above, the study considers only summer rice cultivation which is mainly based on groundwater irrigation and some of the farmers have access to irrigation through groundwater market. With the purchased water a farmer may not be able to bring all of his operational holding under cultivation of summer rice. Under such a situation, it is important to look at the extent of discrepancy between operational holding and area under summer rice. The extent of this difference is presented in Table 4.9.

Table 4.9
Distribution of Sample Farms According to the Extent of Difference between Size of Operational Holdings and the Area under Summer Rice

Extent of difference (in hectares)	Nos. of sample farmers
No difference	83 (43.46)
Difference up to 1 hectare	82 (41.40)
Difference between 1 and 2 hectares	18 (9.42)
Difference of more than 2 hectares	8 (4.19)
Total	191 (100)

Note: Figures in parentheses indicate percentages of column total.

Here the total sample farm is 191 as seven number of farmers considered in the study, have not undertaken the cultivation of summer rice. These farmers are the owners of tubewells and engage themselves in water selling only. It is evident from Table 4.9 that there are differences between the operational holdings and the area under cultivation of summer in 56.54 percent of the total sample farms. The maximum difference between the two is estimated as 3.75 hectare. It is shown in the table that maximum difference lies in the category up to 1 hectare which is about 41.40 percent of the total sample farm units. This is followed by sample farms of 9.42 percent in the category between 1 to 2 hectares. There are only 8 farmers (4.19 percent) which account the difference more than 2 hectares between the two.

4.7.3 Incidence of Tenancy among Sample Farmers:

The details of distribution of tenant farmers are shown in Table 4.10. Tenancy, in the study, is defined as the practice of leasing in land from other farmers.

Table 4.10
Distribution of Tenant Farmers in the Sample According to the Percentage of Leased Area in their Operational Holdings

Percentage of leased-in area to operational holding	Total number of tenant farmers
Below 25	9 (9.38)
25- 50	38 (39.58)
50-75	28 (29.17)
75 and above	21 (21.88)
Total	96 (100)

Note: Figures in parentheses represent percentages of column total.

It is clear from Table 4.10 that 96 out of 198 sample farms, that is, about 48.48 percent of sample farmers, have leased-in land as part of their operational holdings. But in about 51.05 percent of 96 tenant farmers, land leased in constitutes more than half of the farmer's operational holdings. In case of about 21.88 percent of tenant farmers even 75 percent or more of operational holdings were found to be leased in land. In case of 8 tenant farmers (4.04 percent of total sample), the leased- in land constitutes the whole of the operational holdings. This indicates that land tenancy among the sample farmers is very prominent. It has an important implication in the water market practices as most of the literature on water market point out that in many cases, buyers are the tenants of water sellers. However, this interlinkage between land tenancy and water transaction has been taken up for detailed discussion in the next chapter. There are mainly two forms of tenancy observed in the field, viz. fixed rent and output sharing. Under the fixed rent basis, the payment is made on both monetary terms as well as fixed produce basis (usually 8.98 quintals per hectare) though there is no hard and fast rule governing this. The rate has been fixed based on traditional practices and the form of contract is found to be informal. Output sharing as a form of tenancy generally takes two forms: output sharing without cost sharing and output sharing with cost sharing. Output sharing without cost sharing is the dominant in majority of the cases of land tenancy. The mode of payment in output sharing without cost sharing is to share output between

the tenant and the landlord, usually at 50:50 ratios. In a few cases where output sharing takes place with cost sharing with the landlord, two third of the total produce goes to the landlord. In cases where landlord happens to be the water seller, the rates are different and the farmers prefer the tenancy in the form of output sharing with cost sharing. This interlinkage between land tenancy contract and the water contract is examined in the next chapter.

4.7.4 Participation of Sample Farmers in Groundwater Transaction:

Participation of the sample farmers in groundwater transaction is presented in Table 4.11.

Table 4.11
Distribution of Sample Farmers According to Their
Participation in Groundwater Transaction

Participation of farmers	Total number of sample farmers
Yes	180 (90.90)
No	18 (9.09)
Total	198 (100)

Note: Figures in the parentheses represent percentage to column total.

It is evident from Table 4.11 that as high as 90.90 percent of the total sample farmers have participated in groundwater transaction for cultivation of summer rice which is primarily based on groundwater irrigation. The nature of participation of farmers in the groundwater market and the nature of groundwater transaction between them has been taken up for detailed discussion in the next chapter.

4.8 Summing Up:

The broad profile of the sample farmers presented in this chapter, is meant for providing the background for more intensive analysis of the nature, structure and functioning of the groundwater market in the next chapter.

CHAPTER FIVE

STRUCTURE OF THE GROUNDWATER MARKET AND THE UNDERLYING PRODUCTION SYSTEM

In the previous chapter, a broad profile of the sample farmers has been presented. It has been found that about 90 percent of the sample farmers are engaged in groundwater transaction in the cultivation of summer rice. The groundwater transaction is influenced by a number of factors. These include socio-economic conditions of the farm households, presence of rural credit market, land tenure system and characteristics of tubewells, etc. Therefore, it is important to know under what conditions the market for groundwater in the study area has taken place and in what way the market is linked with the existing land tenure system and rural credit market. In this chapter, an attempt is made to obtain a greater understanding of the nature, structure and functioning of the prevailing groundwater market. The available empirical studies on groundwater markets also show that the operation of groundwater market is largely affected by the characteristics of tubewells around which the market has evolved. Since, the market has taken place in the cultivation of summer rice which is primarily based upon groundwater irrigation, it is also important to know the characteristics of underlying production system. Therefore, after looking at the nature, structure and functioning of the market, the characteristics of tubewells and the prevailing system of production under the market, are discussed.

The rest of this chapter is organised under five sections. Section 5.1 deals with the characteristics of groundwater markets with reference to water rights, market arrangement, water contract, water charges, variations in water charges, flexibility in water transaction, dynamics of groundwater markets, etc. Section 5.2 discusses characteristics of the tubewells and their inherent implication for water transaction among the farmers participating in the market. Section 5.3 examines the general characteristics of the production system of the sample farms under different structures of the market. Section 5.4 discusses some other aspects of production and their relevance in groundwater markets. Section 5.5 finally sums up the whole discussion of the chapter.

5.1 The Nature, Structure and Functioning of the Groundwater Market:

The structure and mode of operation of the groundwater market is influenced by a plethora of factors. Khanna (2006) notes that while market structure (such as the different categories of participants in the market), water contracts, water charges, tubewell characteristics, density of market players, number of transactions, etc. are expected to influence exchange between sellers and the buyers; the non-market factors such as land fragmentation, forms of land tenancy, social norms and customs, electricity supply, availability of water conveyance facilities, etc. are expected to influence mode of operation of the market. In the same context, Saleth (1998) also notes that the functioning of water markets is affected not only by their economic linkages with other rural markets but also by non-economic linkages such as local customs, kinship and social relationship. Thus, looking at the nature, structure and the functioning of groundwater market is important to know how groundwater is exchanged between farmers of different categories, how the market and non-market factors influence this exchange and how the market is linked with other rural markets like financial market, land tenure system, etc. (Fujita and Hossain, 1995).

5.1.1 Water Rights and Nature of the Groundwater Market:

Ownership rights over the natural resources play a significant role in the use and management of the resource. There are three laws that govern both ownership and use of groundwater in India. *Firstly*, The Easement Act, 1882 which allows usufructary rights in groundwater by viewing it as an easement connected to the land; *Secondly*, The Transfer of Property Act, 1882 (specially clause 6 (c)), which provides that an easement (groundwater in this case) can be given to one only if the dominant heritage (in this case land) is also transferred; *Thirdly*, Land Acquisition Act, 1889 which asserts that if someone is interested in getting rights over groundwater, he would have to be interested in the land (Narain, 1997). Thus, in the given circumstances defined by the three different laws, in India the owners of land consider water beneath their land as private resource.

In the present study, it has been found that the sample farmers, owning a tubewell, extract water considering groundwater their private property and engage in water selling if the four conditions, mentioned in the first chapter, as laid out by Pant (1992)

are satisfied. There is no such institutional obstacle over the use of groundwater. No tubewell owner has been observed to be constrained by any government regulation. There are no such rules set by the government to influence water selling and buying in the study area. There is also no such social restriction, at the village or community levels, against entering the market. The owners of tubewell sell water without any written contract or agreement with the buyers. As Shah (1993) concludes, “a water market is informal when transaction between water-selling and water-buying households is done without legal sanction”. Thus, the groundwater market in the study area is informal like in Pakistan (Meinzen-Dick, 1996; Hussain et al., 2005; Khair et al., 2012), in China (Zhang, 2006), in Nepal (Bhandari and Pandey, 2006), in Bangladesh (Fujita and Hossain, 1995) and in different states in India (Saleth, 1991; Shankar, 1992; Pant, 1992; Shah, 1992, 1993; Dubash, 2000; Singh, 2003; Khanna, 2006; Singh and Singh, 2006; Sharma and Sharma, 2006; Banerji et al., 2006 & 2012; Manjunatha et al., 2010, 2011a; Dutta, 2012, etc.).

It has also been found that water transaction in the study area is limited to water selling and water buying among the farm households that live in the same village and work in the same crop field or that live in different villages but work in the same crop field. It is due to the fact that access to groundwater is constrained by the absence of conveyance facilities or inadequate conveyance facilities where they are present. As a result, water transaction between willing buyers and sellers is highly confined to a village and a group of farmers having agricultural plots attached to each other or at a distance which is technically feasible to be connected by any conveyance facility. In this context, the groundwater market, found in the study area, is a localised institution. This observation supports findings of Shah (1993) and Jacoby et al. (2004) that “localized nature of water market is almost universal”.

5.1.2 Market Arrangement:

There are six alternative market arrangements found in the field which facilitate the farmers an access to groundwater. These are labeled as “self-users+sellers”, “buyers”, “self-users+sellers+buyers”, “self-users+buyers”, “owners+sellers” and “self-users”. These categories are defined in the following manner.

In the first of such arrangement, farmers with independent or joint ownership (or both individual and joint ownership) of tubewell or tubewells use water for cultivating own plots as well as sell water to needy farmers in the vicinity of the tubewell, usually after meeting their own requirements. This, in the literature of water market, is often termed as the “self-users+sellers” of water. The second desirable arrangement refers to the category of farmers who do not own tubewell on their own, but undertake cultivation by purchasing water from the owners of tubewells in the neighbourhood of their crop fields. This in the literature of water market is termed as “buyers” of water. This category of participants in groundwater markets, buy water from the nearest single or multiple tubewells usually adjacent to their agricultural plots. However, the possibility of water purchase from any distant source cannot be ruled out when there is suitable arrangement for water conveyance. The third possible arrangement is the independent or joint ownership of tubewells, where the owner of tubewells cultivate their plots with water from own tubewells, sell water to willing buyers after meeting their own requirement and buy water from other tubewells in another location, especially when their cultivable land is fragmented in two or more than two plots. This category of participants, in the groundwater market, is termed as “self-users+sellers+buyers”. In the fourth possible arrangement, the farmers with independent ownership or joint ownership of a tubewell or tubewells use water from their own tubewells for own use in one plot and buy water from other tubewells in another plots. This category of participants in the market is termed as “self-users+buyers”. The fifth form of arrangement, found in the study area, refers to a situation in which some farmers have invested on tubewells not to meet their own irrigation requirements but for using it primarily for selling water to other farmers. This category of participants in the market is termed as “owner+sellers”. Shah (1993) has noted this as specialised additional occupation for some farmers in Kheda district of Gujarat. When we look at the users of groundwater, besides these five different categories of groundwater users, there is another group termed as “self-users”. These farmers usually with individual or group ownership, use water from the tubewells for own cultivation and do not engage themselves in either selling or buying of water. The distribution of the sample farmers under these six different structures of groundwater markets according to their size of operational holding is presented in Table 5.1.

It is clear from Table 5.1 that a large majority of the sample farmers, about 90.90 percent) are engaged in water transaction. The “buyers” alone constitute the largest segment (39.90 percent) followed by “self-users+sellers” (38.38 percent), “self-users” (9.09 percent), “self-users+sellers+buyers” (7.07 percent), “owner+sellers” (3.54 percent) and “self-users + buyers” (2.02 percent). The majority of the buyers are found to be marginal (56.82 percent) and small farmers (41.54 percent). This implies that about 98.36 percent of the buyers are in the category of small and marginal farmers. Buyers in the semi-medium category are only 5.13 percent. The size-wise analysis of buyers explicitly shows that when the farm size increases, the number of buyers has decreased correspondingly. With relatively larger farm size, the number of buyers is very less which in the sample is about 5.13 percent of the total sample farms. It can be concluded that buyers in the groundwater markets are usually small and marginal farmers. This finding is similar to the results of Fujita and Hossain (1995) in Bangladesh; Meinzen-Dick (1997) in Punjab province of Pakistan; Zhang et al. (2007) in China; Bhandari and Pandey (2006) in Nepal; and a couple of studies such as Deepak et al. (2005), Sharma and Sharma (2006), Khanna (2006), Singh and Singh (2006), Manjunatha et al. (2011a), Dutta (2012), Manonmani and Malathi (2012), etc. in India.

Table 5.1
The Distribution of Sample Farmers According to the Structure of the Groundwater Market

Size class of operational land holding (in hectare)	Category of participants in the water market						Total
	Self-users	Self-users+sellers	Self-users+sellers+buyers	Self-users+buyers	Buyers	Owner+sellers	
Marginal	5 (5.68)	25 (28.41)	2 (2.27)	-	50 (56.82)	6 (6.82)	88 (100)
Small	5 (7.69)	25 (38.46)	5 (7.69)	2 (3.08)	27 (41.54)	1 (1.54)	65 (100)
Semi-medium	8 (20.51)	22 (56.41)	6 (15.38)	1 (2.56)	2 (5.13)	0	39 (100)
Medium	0	4 (66.67)	1 (16.67)	1 (16.67)	0	0	6 (100)
Total	18 (9.09)	76 (38.38)	14 (7.07)	4 (2.02)	79 (39.90)	7 (3.54)	198 (100)

Note: Figures in parentheses indicate percentage of the row total.

The size-wise analysis for sellers, however, delineates a mixed picture. Out of the total sample “self-users+sellers”, about 65.78 percent are marginal and small farmers. With the increase in size of farm holdings, the number of “self-user+sellers” has decreased as the sample farmers in semi-medium and medium categories of farm holdings constitute about 28.94 and 5.26 percent respectively. In the “self-users+sellers+buyers” category, out of the total sample farmers of 14, the number of farmers engaged in water selling has increased from 2 to 6 along with increase in size of the land holdings which however, has plummeted to 1 when farm size is medium size holding. Taking all the categories together, the total number of sellers in one or other form of selling activities is 97 out of which 65.98 percent are marginal farmers (34.02 percent) and small farmers (31.96 percent). But against this, about 28.86 percent are in semi-medium and 5.15 percent in medium farm holding categories. This implies that the majority of the water sellers are concentrated in the category of small and marginal farmers. This is in contrast with the findings of majority of the existing literature on water markets which have reported that the water sellers are usually the large farmers whereas the buyers are small farmers (Saleth, 1998). However, the finding of the study resembles the results of Mukherjee (1992) who in a study in West Bengal has found that as high as 84 percent of water selling is done by marginal and small farmers. Dubash (2000) has found incidence of water selling by small farmers in Paldi village in Banaskantha district of Gujarat. In the similar context reference can be made of Manjunatha et al. (2011a, 2011b) where the researchers have found a few small and marginal farmers engaged in water selling in one of the *talukas* of eastern dry zone of Karnataka. This study, thus, marks a deviation from the established theory in the literature of water market that sellers are always the large scale farmers. Thus, when the farm size increases the number of buyer decreases. But the reverse is not always true for the sellers, i.e. though increase in farm size may cause farmers to own tubewell, the farmers may not be the sellers.

Though the number of sellers in large farm category is low, the size of their holding may be greater than the buyers. The size of operational holdings of the farmers under different categories of groundwater users is presented in Table 5.2.

It is clear from Table 5.2 that the average size of operational holdings of the buyers is 0.9 hectares while the minimum and maximum size of operational holdings are 0.20

hectares and 3.08 hectares respectively. But the average size of operational holdings of the sellers in all categories (except the “owner+sellers”), remains higher than the average size of operational holdings (1.35 hectare) for all the market participants. This implies that, on the average, the size of operational holdings of the water sellers is comparatively larger than the buyers. However, there is an exception to this trend. As evident from Table 5.2, a few members of the group “owners+sellers”, though do not hold any cultivable land are in the possession of shallow tubewells and engage in water selling. This category of water sellers owns the tubewell primarily for selling water to other farmers and to their tenants. This dimension of the market has not been mentioned by Pant (1992) while explaining the conditions for the existence of groundwater market. Thus, on the seller’s side, it shows that the market has helped some of the tubewell owners to sell water not only in excess of their own use on self-operated area but also taking groundwater pumping as an additional source of income. It also suggests that the market is not residual to the buyers in all cases.

Table 5.2
Size of the Operational Holdings of Different Categories of Groundwater Users

Categories of water users	No. of Farms	Minimum (in hectare)	Maximum (in hectare)	Average (in hectare)	Standard Deviation
Self-users	18 (9.09)	0.40	3.34	1.68	0.99
Self-users+sellers	76 (38.38)	0.27	4.95	1.64	1.05
Self-users+sellers+buyers	14 (7.07)	0.27	4.41	2.09	1.24
Self-users+buyers	4 (2.02)	1.07	4.01	2.58	1.59
Buyers	79 (39.90)	0.20	3.08	0.90	0.55
Owner+sellers	7 (3.54)	0.00	1.74	0.29	0.65
Total	198 (100)	0.00	4.95	1.35	1.00

Notes: Figures in parentheses indicate percentage of the column total.

5.1.3 Size and Significance of the Groundwater Market:

Since the importance of groundwater market lies in its role in extending access to water to farmers without WEDs, looking at the size of the market is necessary. There is no

macro level estimate for the size of water markets in India. However, some empirical micro studies from different parts of the country have estimated the size of the market in the respective study areas primarily using two indices: percentage of total water output traded and the average number of buyers per water seller (Saleth 1998). For example, Shah (1993) has estimated that more than 50 percent of the gross area irrigated by private modern WEDs is served by groundwater markets. Saleth (1998), using a methodology based on pumpsets rental data put the figure at 6 million hectares or 15 percent of the total area irrigated by groundwater. Mohanty and Gupta (2002) assuming a contribution of irrigated cultivation to total output at \$230/ha/year, have estimated the total value of output due to water sales to be \$1.38 billion/year. There is a great degree of variation in the size of groundwater markets among different states. In northern Gujarat, nearly 80 percent of the total irrigated acreage is irrigated through water markets (Shah, 1993) while in Eastern and Western part of Uttar Pradesh it is 73 to 79 percent respectively (Pant, 2002). Similarly, about 40 to 60 percent of irrigated land is irrigated through water markets in Allahabad district of Uttar Pradesh (Shankar, 1992) followed by 30 percent in Vaigai Basin in Tamil Nadu (Janakarajan, 1993). Dubash (2000) has noted that in Ratanpura village of Mehsana district of Gujarat, between 61 percent to 71 percent of the water pumped is sold and 90 percent of landed households depend fully or partly on purchased groundwater where 44 percent rely entirely on purchased groundwater for irrigation.

The size of the water market in this study has been measured using the area approach. The area here refers to the irrigated area by the purchased water. In the study, a total 119 shallow tubewell owners irrigate a gross area of 308.66 hectares. Thus, the average irrigated area per tubewell owner is 2.59 hectares including both own use and water selling. These owners of tubewells altogether possess 185 pumpsets (both diesel and electric). Thus, the average irrigated area served by one pumpset is 1.67 hectares. Out of this total irrigated area, 144.65 hectares is for own use whereas the rest is for selling water. Thus, about 53.19 percent of the total irrigated area has been served by water selling which is higher than the use of the same for own purpose. This figure has been found to be higher compared to Allahabad district of Uttar Pradesh where in a study, Shankar (1992) has estimated it to be 40 percent but lower than in Gujarat where Shah (1993) estimated it to be more than 80 percent and in West Bengal where Kolavali and Atheeq (1990) found it to be up to 64 percent. The total area of 164.18 hectares served

by water selling is distributed among 354 buyers, each buyer owning 0.49 hectares of land on the average. The total number of buyers per seller is found to be 3.64. This number is found to be quite low compared to Gujarat where it stood between 2 to 80 buyers per seller across regions Shah (1993). The apparently higher number of buyers in Gujarat can be attributed to use of deep tubewells having a boring depth of up to 400 meter and large pumps (30 to 75 hp), and vast pipeline networks found in the state Saleth (1998).

Looking at the size of the water market from the buyers' point of view, it has been found that a total of 97 sample buyers irrigate a gross area of 85.68 hectares of cultivable land. These sample buyers include only buyers and those who are also water sellers and irrigate 0.88 hectares of land, on the average. Out of all buyers, about 74.23 percent have purchased water from one seller followed by 18.56 percent purchasing from two sellers and the rest 7.22 percent have purchased from three sellers. The buyers' choice for multiple sellers is primarily due to fragmentation of holdings which spread across different locations. The fact that buyer's average cultivated area (buyer's cultivated area and irrigated area are same) is lower is not surprising as the majority of the buyers are small and marginal farmers and in most cases they are the tenants leasing in small plots of land from the water sellers-cum-land owners.

The above discussion on the size of the water market from seller's point of view indicates that at individual level the buyers' average cultivable area is lower than that of sellers. However, total cultivable area of all the buyers combined together may be larger than that of the sellers due to presence of multiple sellers for a particular buyer as evident from buyer's point of view. This finding is similar to Shah's (1993) observation on the size of water market that "... up to half or more of the land area served by private modern WEMs in many parts of India is likely to be owned and operated by the buyers of water".

5.1.4 Forms of Water Contract:

Existing studies on water market throw light on different aspects of forms of water contract between water buyers and sellers. Following three aspects relating to water contract have been found in the study.

Firstly, the sample water buyers cultivate either in their self-owned plots or leased-in plots from other farmers, not necessarily the water sellers, or in both the plots. When the sample water sellers are the landowners, no land owner has been found to have provided water to a tenant-cum-buyer as part of an interlinked land tenancy contract. There is no input transaction, other than water, when water contract is interlinked with land tenancy contract. However, the provision of water is not free. In the prevailing market, the buyers are required to pay the existing rate for water transaction as well as for land tenancy. There are also instances where the buyers provide unpaid labour in return of water. This practice of providing some other services by the buyers to the water sellers is more stringent when water contract is interlinked with the land tenancy. In all other cases, contract is strictly for groundwater and the water charges capture the usage charge of the WEDs. *Secondly*, there is no formal or informal restriction on the choice of the contract. The choice depends on the individual characteristics of the farmers i.e. a risk-averse buyer prefers output sharing contract whereas a risk-averse seller prefers cash transaction (Banerji et al., 2006). If conflict arises regarding choice between the two, the seller's choice is the ultimate one as in most of the cases a buyer is not left with any alternative seller. Also many of the transactions are interlinked. However, in the field, it has been found that there is predominance of non-cash transaction and the choice is made by the buyers. No sample sellers have been found to force buyers in choosing the contract. *Thirdly*, contracts are, to some extent, flexible between the buyers and seller when they have personal relationships with each other. This is reflected in the form of concession on water charges given by the water sellers to the buyers with personal relationships. The associated aspects of these three alternative forms of water contract are discussed in the next sub-sections in details with the inputs from the field.

5.1.5 Mode of Payment:

There are three modes of payment of purchased groundwater: hourly rates, area based rate and volumetric rate. Under the hourly rate of payment, water charge is determined based on the number of hours of operation of a pumpset in irrigating buyer's cultivated plots. Under the volumetric approach, the water charge is based on the quantity of water discharged by a pumpset per hour or per acreage of buyer's cultivated land. The earlier empirical studies have pointed out dominance of hourly rate in water transaction

(e.g., Pant, 1992; Janakarajan, 1993; Palmer-Jones, 1993; Satyasai, 1997; Shah and Ballabh, 1997; Hussain et al. 2005; Jha and Sinha, 2008; Khair et al., 2012, etc.). However, in the study area water charge realised is based on area approach where the amount of water charged is based on the amount of land irrigated. The mode of transaction in the market is found to be taking place in both cash and kind. The non-cash water charges are of two types: fixed charge and output sharing. The output sharing takes two forms, viz. output-sharing with or without cost sharing. The pattern of water charge realised in the study area is presented in Table 5.3. The information on water charge has been collected from both the buyers and sellers in the water market to see the nature of transaction between different types of buyers and sellers.

Table 5.3
Nature of Transaction across Different Categories of Market Participants

Mode of Transaction	Category of Participants in Groundwater Market					Total
	Self-users + Sellers	Self-users + Sellers + Buyers	Owner + Sellers	Self-users + buyers	Buyers	
Cash	17	6	0	3	15	41 (22.77)
Kind (with fixed charge)	51	5	3	1	59	119 (66.11)
Kind (with output sharing)	5	2	3	0	0	10 (5.55)
Cash and Kind (with fixed charge)	0	0	1	0	0	01 (0.55)
Cash and Kind (with output sharing)	2	1	0	0	5	08 (4.44)
Cash, Kind (with fixed charge) and Kind (with output sharing)	1	0	0	0	0	01 (0.55)
Total	76	14	7	4	79	180 (100)

Notes: (a) Figures in parentheses indicate percentage of the column total.

(b) Self-users are excluded as they do not engage in water transaction.

The table shows that the prevalent mode of transaction in the market is a combination of both cash and kind. However, the instances of non-cash transaction are dominant. While about 74.22 percent of the sample farmers have made the transaction in kind, about 23.20 percent of farmers have paid or received water charge in cash. Under kind based payment, about 66.49 percent of the total sample farmers have paid a fixed charge and 7.73 percent of the total sample farmers have made the payment on output

sharing basis. Under a fixed charge contract, water buyers pay a fixed amount of the produce for a season for a specified irrigation acreage generally one *bigha* (equivalent to 0.133 hectare) after the harvest of that crop. Under an output sharing in-kind payment, the buyers pay for the water for the season by providing a certain portion of their product after the harvest of that crop. The fact that most of the sample farmers (77.31 percent) have preferred kind-based payment is mainly for two reasons: *firstly*, they face difficulties in the beginning of the irrigation season to pay for water in cash when they also need to pay for fuel (in case of a diesel operated pumpsets), fertilisers, seedling and labour. *Secondly*, through this they can shift the burden of irrigation cost to the water sellers for about five to six months. Though the dominant mode of in kind transaction takes the form of fixed charge, farmers in the study area also has preferred output sharing as through this they may get partial or full concession at the time of payment when there is crop failure¹.

The analysis has an important implication for the development of groundwater markets in the study area. Shah (1991) in his seminal work on water market has opined that the prevalence of non-cash transaction is “an artifact of early stage of water market development” and drive towards maturity will “... give way to one or two standard and widely used contract; and outright cash payment gains precedence over crop sharing contracts”. Following Shah’s this evolutionary thesis² of water market development, the water market observed in the study area may be considered to be in its early stage of development. Though Shah’s finding supports the findings of Choudhury (1990), Dubash (2000) has found no empirical evidence in support of Shah’s proposition. Dubash concluded referring to Aggarwal (1999), that in water market non-cash transactions are widely dominant and stubbornly persistent over time.

5.1.6 Water Charge and Nature of the Market:

As explained in the preceding section, water charge is made either in cash or in kind or both cash and kind. Under the cash transaction, water buyers pay a fixed amount of cash once in a season for a specified acreage, normally 0.133 hectares which is independent of the cost of fuel for operating the pumpset in case of a diesel operated tubewell. In kind payment either with fixed charge or output sharing, as explained earlier, the water buyers make payment after the harvest of the crop. The general rule prevalent in the study area is that the expenses on fuel/diesel are borne by the buyers

themselves irrespective of the mode of payments especially when the water is bought from diesel operated pumpsets. The prevalent water charges paid by the sample buyers under cash-based payment are presented in Table 5.4.

Table 5.4 shows that the average price charged for water per hectare of land, for the sample buyers participating in the groundwater markets is ₹ 3, 361.50 if water is bought from a diesel operated tubewell and ₹ 5, 695.87 if water is bought from an electric powered tubewell. The price varies from ₹ 2, 988.00 per hectare to ₹ 4, 482.00 per hectare when water is bought from diesel operated tubewell.

Table 5.4
Water Charge in Case of Cash-based Transaction

Types of tubewell	Amount per hectare (in Rs.)		
	Minimum	Maximum	Average
Diesel operated tubewell	2988.00	4482.00	3361.50*
Electricity operated tubewell	4482.00	5976.00	5695.87

*when operational cost of diesel tubewell is taken into account the water charge for a diesel operated tubewell will be ₹11,729/-

The field observation shows that the difference in the water charges depending on the sources of power of the tubewell, is mainly due the fact that, in case of diesel operated tubewells the fuel is bought by the buyers themselves while in case of electricity operated tubewells, the buyers are not required to pay for the total electricity units consumed for operating the pumpsets. Thus, the water charge for an electricity operated tubewell is the total value (i.e. water charge + operational cost) . When operational cost of diesel operated tubewell is taken into account, the total value of diesel operated tubewell becomes ₹11,729/- per hectare of land. The presence of such a difference in water charges depending on the types of fuel/power used for the operation of the tubewells is also reported in other parts of the country. For example, based on findings of a number of studies from Punjab, Uttar Pradesh and Gujarat, Saleth (1998) has concluded that the hourly rates vary from about \$0.10 to \$1.30 for electric pumps and \$0.20 to \$0.60 for diesel pumps³.

The water charges based on kind payment (with fixed charge) is shown in Table 5.5. It is evident from the table that the average water charge, under the fixed charge in kind

payment system is 7.47 quintals per hectare, the minimum and maximum being the 5.97quintals/hectare and 11.95 quintal/hectare respectively when water is bought from the diesel operated tubewell. The water charge under this mode of payment is almost double, that is 13.65 quintal per hectare, when the water is bought from the electric operated tubewells. In order to express the in-kind water charge in terms of monetary value, the total kind payment is multiplied by the prevalent average market price of the output (which is ₹ 712.50 per quintal). It has been found that the value of average water charge for electric tubewells is ₹ 9725.62/- which includes cost of water pumping. The total value of water charge (water charge + operational cost) for diesel operated tubewells has been found to be ₹ 14,027.66/-. It clearly indicates that water charge for diesel operated tubewell is higher than the water charge for electric tubewells.

The prevalent rates for output sharing among a few sample buyers are found to vary from one-third to two-thirds of the total produce. This rate is almost same as reported in other studies on water markets. For example, Kajisa and Sakurai (2003) in a study in Madhya Pradesh found it to be ranging from 30 percent to 40 percent. Similarly, Fujita and Hossain (1995) in their study of water markets in northwest Bangladesh have found it to be either 33 percent or 40 percent. In a few instances, the water charge under output sharing payment system is found to be one third of the total produce. Unlike the prevalent rates in other studies, mentioned above, this is found to be a bit higher. However, on enquiry in to this, it has been found that the few buyers, who have agreed to share half or more than half of their produce as payment for water, are tenants of the water sellers and the water sellers also share costs incurred on other inputs with these buyers.

Table 5.5
Water Charge in Case of Kind (with fixed charge)-based Transaction

Types of tubewell	Amount per hectare (in quintal)		
	Minimum	Maximum	Average
Diesel operated tubewell	05.98	11.95	07.41
Electricity operated tubewell	08.96	17.93	13.66

The relatively higher range of water charge under output sharing mode of transaction may point to the possibility of Marshallian inefficiency in water contract as pointed out by Kajisa and Sakurai (2003). The variation in prices in both cash and kind forms of

water contract among a few sample buyers is found to be prevalent at village level also. In the present study, the price variation among buyers within a village is prevalent in two villages out of 11 villages where cash based transaction is practised. In villages where in-kind transaction is in practice, price variation among buyers of same village exists in only 4 villages out of 22 villages. This variation is found to be 33 percent of the average water charge. However, this variation is found to be less compared to Janakarajan (1994) who has found a large variation in pricing both within and between villages in Southern Tamil Nadu covering 27 villages. Prasad (1991) in his study on water market in Bihar also has noted presence of large variation in water charges practised by the water sellers who belong to large land holding class. A large variation in prices has also been reported by Kajisa and Sakurai (2003) in their study on water markets with inputs from six villages in Madhya Pradesh. The variation in prices in the present study is mainly due to the fact that in the villages where the price is charged relatively higher, the soil quality in the crop field has been found to be sandy and the depth of boring is also relatively high. The presence of price variation in few sample villages has indicated a situation of relative water scarcity. Since there are few cases of price variation among buyers of same village, the market may be considered to be relatively competitive at the village level. This finding of the study is more akin to findings of some other studies which find the market competitive in states like Andhra Pradesh, Punjab, West Bengal, Uttar Pradesh, Orissa, etc. (Saleth, 1998).

5.1.7 Inter-linkage between Water Contract and Land Tenure System:

Water markets are closely linked with other rural markets like financial markets and land tenancy markets (Fujita and Hossain, 1995; Palmer-Jones, 1994; Saleth, 1998; Jacoby et al., 2004; Kajisa and Sakurai, 2003, etc.). Looking at the presence of tenancy among farmers under different structures of water markets is important as access to water by the small and marginal farmers also depends on whether the farmers lease in land or not from the water sellers (Meinzen- Dick, 1992, 1998). The incidence of land tenancy among the sample farmers is shown in Table 5.6.

Table 5.6
Extent of Tenancy Among the Participants of Water Market

Types of participant	Nos. of tenants	Fixed rent/produce	Output sharing		Mortgage
			Output sharing (with cost sharing)	Output sharing (without cost sharing)	
Buyers	31 (31.95)*	21 (70.00)	1	7	1
Sellers	41 (42.27)*	25 (60.98)	0	16	0
Total	71	46 (64.79)	1 (1.40)	23 (32.40)	1 (1.40)

* Figures in parentheses indicate percentage of the total number in each category.

It is evident from Table 5.6 that about 31.95 percent of the total water buyers have leased in land from the water sellers and about 42.27 percent of the total sellers have leased out land to the water buyers. The table also reveals that about 64.79 percent of the total cases of tenancy have taken the form of fixed charge whereas about 32.40 percent is based on output sharing.

It has been found in the field that the existing average rate of water with tenancy is about 14.94 quintals per hectare out of which about 8.96 quintal per hectare is charged for the land. No landlord has been found to be discriminating water charges between his tenants and other buyers of water. This finding is not similar to the finding of Jacoby et al. (2004) who in their study on water markets in Punjab province of Pakistan, have found presence of price discrimination exercised by the landlords between these two groups of buyers of water. Dubash (2002) in a study in North Gujarat also has noted differential treatment made by the water sellers between their tenant buyers and other buyers. Dubash noted that the tenant buyers are required to make payment in fixed share basis when the dominant form of exchange is flat cash price per hour. In the field, a few buyers have been found to be leasing in land from the water sellers, abandoning their own cultivable land. This is mainly for two reasons: firstly, there is hardly any water seller in the vicinity of their own plots and secondly, there is assured and adequate water supply on the leased-in land from the water sellers throughout the season. This indicates a stronger inter-linkage between the water market

and existing land tenure system among sample farms under different market structure that affect reliability of the market. This issue of reliability of water markets is taken up for a detailed investigation in chapter seven.

5.1.8 Flexibility in the Water Contract:

Palmer-Jones (1994), Meinen-Dick (2000) and Dubash (2002) have outlined the complexity in the nature of water contracts which is mostly governed by the social processes. As delineated in the previous sections on water charge, water charge is not fixed by any formal written agreement between the buyers and the sellers. At the same time, it has been observed that the sample buyers' choices of water sellers are also restricted due to lower tubewell density in the crop fields, and limited availability of conveyance facilities if buyers' plots are located in a distant plot (Hussain et al. 2005). This lends the water sellers some market power to charge different prices from different buyers (Shah, 1993; Wood, 1995; Shah and Ballabh, 1997; Pant, 2003; Jacoby et al., 2004). Though, sample sellers' are not found to have charged different water charges from different buyers, some of them have been found to have given concession on water charges to some of their buyers.

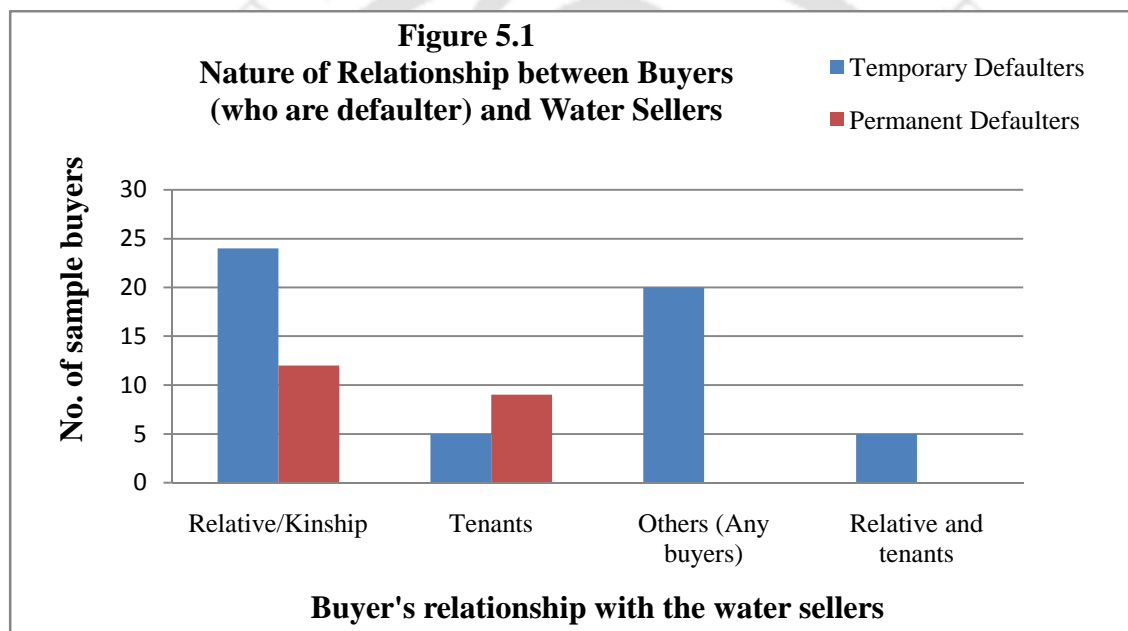
It has been found in the study that about 25.57 percent of the total sample water sellers have given concession on water charges to their buyers. On enquiring who are the buyers enjoying this concession, it has been found that about 56 percent of the sellers have given concession to their brothers and the rest have given concession to their relatives. In two cases, the sellers have given full concession to their brothers-cum-buyers who suffered serious illness during the period of cultivation. This finding is similar to the results of Shah (1993) who has found that transaction between water buying and water selling farm households were personal in a few cases. However, this finding is not similar to the results of Zhang (2006) who has found that in Northern China groundwater markets are almost fully impersonal.

The extent of this price concession in the study area varies from 10.00 percent (1.49 quintal per hectare) to 23.3 percent (5.97 quintal per hectare). In majority of the cases, about 2.98 quintals per hectare concession is given. While the brothers of the water sellers have enjoyed either 5.97 quintal per hectare concession from the water sellers or

full concession (conditioned by serious illness), the relatives of the water sellers have enjoyed a concession of 2.98 quintal per hectare.

5.1.9 Overdues in the Payment of Water Charge:

The studies on water market report that there always remains an overdue in the payment of water charge by the water buyers (Khanna, 2006). In the present study, a few buyers have been found to be defaulters in making payment of water in time. Out of a total of 97 water sellers, about 55.67 percent have reported that there remains an overdue in the payment of water charge. The number of buyers under different categories reported to be the defaulters is shown in Figure 5.1.



It is clear from Figure 5.1 that the sample buyers, who are the relatives of the sample water sellers, are the highest defaulters, which is about 44.45 percent of the total defaulters. This is followed by buyers, who are neither the relatives nor the tenants of the water sellers. This is found to be about 37.04 percent of the defaulters. Compared to these two groups, the number of tenants who failed to make payment on time is less, which is 9.26 percent of the total defaulters. A few buyers, who are tenants and relatives of the water sellers, have also been found to be defaulting on payment of water charge. Though a majority of buyers have remained defaulter for a year, out of the total defaulters, about 38.88 percent are permanent defaulters. Among the permanent defaulters, about 57.14 percent are relatives of the sample water sellers. Thus, it is clear

that brothers and close relatives of the sample water sellers are the defaulters in the payment of water charges. Thus, there are free riders in water market. It raises a serious question why the sellers have not retaliated to punish these permanent free riders? When institutional economics dealing with resource management suggests that free riders are usually punished –sometimes, severely (Ostrom 1990, Baland and Platteau 1996) the study results here suggests that if the free riders are the sellers’ relatives, they are allowed to continue to behave like that ‘permanently’. If they are allowed to behave in this way the market will not be sustainable in future.

5.1.10 Water Charges and Other Services Rendered by the Buyers:

The nature and mode of operation of the village level groundwater market also state that the price does not always guarantee access to water (Wood, 1995). In addition to water charge, some of the buyers are required to render some other services to the water sellers like operating the pump and irrigating the well owner’s field (Janakarajan, 1993, 1994). In the present study too, about 35.05 percent of the buyers are found to provide some sort of free services to their respective water sellers in addition to the water charge paid. The different types of services provided by the buyers are listed in Table 5.7.

Table 5.7
Distribution of Buyers Providing Services to the Water Sellers and Types of These Services

Types of other services	No. of buyers
Protecting and operating the pumpsets in the crop field	4 (11.76)
Transporting the pumpsets to the field	7 (20.59)
Any work asked by the water sellers & protecting the pumpsets in the field	3 (8.82)
Any work asked by the water sellers	20 (58.82)
Total	34 (100)

Note: Figures in parentheses indicate the percentage of the column total.

It is evident from Table 5.7 that as high as about 58.82 percent buyers have to provide any sort of services demanded by the water sellers. About 20.59 percent of the sample buyers have to help the sellers in transporting the pumpset to and from the crop field. Another 11.76 percent have to render their services in operating and protecting the

pumpset in the crop field. The buyers are required to provide these services in order to maintain a cordial relationship with the sellers, so that they are provided with timely supply of water at the time of requirement. A few sample buyers (8.82 percent) providing other services refused to render these free services but were denied water by the sellers leading to giving up of cultivation by the farmers. There is also a preferential treatment of the buyers by the sellers. Normally, siblings and close relatives are provided with high preference in providing water by the sellers. The presence of this type of preferential treatment has also been reported by Narayanamoorthy (1991) in a study on water markets in Puddukkottai district of Tamil Nadu. From this analysis, it may be concluded that market practices are not purely based on conventional economic model which is endogenous to the water market. Instead, the water sellers exercise some monopoly power,⁴ though not reflected in the water charges, through some other means which are exogenous to the market system. Similar type of practice is also reported by Ray (1998) in the operation of rural credit market. In the light of these findings, a comparison with a few aspects of water market reported by existing studies on water market can be made. *Firstly*, the market in the study area is like the market in Gujarat (Shah, 1993) and Tamil Nadu (Janakarajan, 1994) where the market is found to have more oligopolistic and monopolistic in nature; *Secondly*, it resembles the observation made by Saleth (1998) that "...in a market where the buyers and sellers have about the same sized farms and share a common socio-economic background is likely to be more equitable and less exploitative". *Thirdly*, the market in the study area is less exploitative like the same in case of Madhya Pradesh where in a study Kajisa and Sakurai (2003) have found that the sellers' behaviour is not exploitative.

5.1.11 Dynamics of Groundwater Markets:

Groundwater market in the state is developed hovering around the shallow tubewells. The majority of the shallow tubewells are diesel operated. However, due to rise in diesel prices, some adulteration in diesel takes place in operating a pumpset. In certain places where electricity connections are available, farmers have resorted to electric motors. But electric motors are operated with domestic connection. Since in the market, normally fuel expenses are borne by the buyers in operating a pumpset, some of the buyers have a tendency to use kerosene to minimise the fuel expenses. Most of the sellers do not prefer such type of adulteration in fuel forcing existing buyers to abandon

cultivation of summer rice which is primarily based upon groundwater based irrigation. This may result in the decline in market transaction. Therefore, an attempt has been made to understand whether there is reduction in market transaction in the study area.

It has been found in the field that about 45.83 percent of the existing water sellers who are engaged in water selling for more than 20 years, have reported decline in number of buyers over the years. Whether market transaction is declining over time is elicited from the water sellers who have been asked to list the factors that they perceive to be the most probable reasons for this. Many sellers have also reported that their existing buyers have been declining as the most of them have shifted to electricity operated tubewells. Since this kind of transformation does not result in net reduction of buyers they are not listed as the reason for declining number of buyers. Since many sellers do not allow the buyers to use kerosene in diesel operated pumpset, buyers who tend to use kerosene or find it difficult to afford diesel (which seems to be costlier than kerosene) has been permanently refused water. This results in the net reduction in numbers of buyers because a buyer who is refused under this ground, do not find alternative seller as the market is mostly constrained by limited availability of the conveyance facilities if source of irrigation lies in a distant plot. The reasons for decrease in number of buyers over the years, perceived by the sellers, are presented in Table 5.8.

Table 5.8
Reasons for Decreasing Number of Buyers as Perceived by the Water Sellers

Reasons	Nos. of sample sellers
A few earlier buyers got their own pumpset	22 (33.33)
A few buyers gave up cultivation as they found either price of diesel or price of labour was high	23 (34.85)
Not selling as the electricity supply is irregular	4 (6.06)
Refused to sell as the buyers wanted to use kerosene instead of diesel	9 (13.64)
The machine got older so the seller himself is not selling water	8 (12.12)
Total	66 (100)

Notes: Figures in parentheses represent percent of the column total.

It is evident from Table 5.8 that out of total sample sellers who have cited that their number of buyers has been decreasing over the years, about 34.85 percent have cited that some of their earlier buyers have given up cultivation of summer rice due to increase in prices of either diesel or labour. This is followed by about 33.33 percent sellers who have attributed to the procurement of own pumpset by some of the earlier

buyers as a reason for reduction in number of buyers in the groundwater markets. A few owners of electric motor (6.06 percent) had to reduce number of buyers as electricity supply has not been regular which, in turn, makes the sellers unable to meet buyer's need at the time of requirement. While about 13.64 percent of the sample sellers, have refused to sell water to buyers preferring to use kerosene in diesel operated pumpsets, 12.12 percent of the respondents have refused to sell water as their pumpsets are quite old. Thus, most of the sellers perceive that labour shortage, steep rise in input prices, particularly chemical fertiliser and inadequate procurement price for the crop are among the factors that drive most of the buyers to give up cultivation of the summer rice resulting in net reduction in market transaction.

5.1.12 Dispute over Use of Groundwater among Farmers:

The use of groundwater for irrigation in India has increased considerably resulting in groundwater depletion in many parts of India (Moench, 1992, 2000; Chandrakanth et al., 2004; Scott and Shah, 2004) and conflict among the farmers (Cullet et al., 2012; Janakarajan and Moench, 2006; Foster and Gardunu, 2004). Most of the literature on groundwater markets have pointed out that there is dispute over the use of groundwater owing mainly to the scarcity of the resource (Shah, 1993; Janakarajan and Moench, 2006). However, in the context of the present study, no such dispute over the use of groundwater has been noticed. The possible reason for this may be due to the fact that the state, in the eastern part of India, has sufficient groundwater reserves unlike other parts of the country. As mentioned in chapter 3, out of the total annual replenishable amount of groundwater, only 22 percent of it has so far been developed for agricultural, industrial and domestic purposes. It leaves plenty of scope for development of groundwater based irrigation in the state. However, most of the market participants (about 43.75 percent of the sample water sellers who have faced non-availability of water) reported failure of the pumpsets in delivering sufficient water when all the pumpsets in the field are operated at the same time. Owing to this, a few farmers have expressed their apprehension that unfettered penetration of pumpsets may cause conflict over the use of groundwater in near future. The possible reason for this conflict as they have understood is the failure of the tubewells to deliver sufficient water when all pumpsets are operated concurrently indicating that there is relative scarcity of groundwater in a few locations. Though the magnitude of the problem is not acute and

seasonal in nature, this farm level evidence suggests presence of common pool resource problem of agricultural groundwater extraction. It can also be concluded that the market is found to be contributing to such common pool resource problems of groundwater extraction in the study area.

Regarding complaints raised by the farmers about conflict that arises over the use of groundwater, due to relative scarcity of groundwater, the farmers opine that everybody understands the problem and adjusts accordingly. Thus, farmers have been found to have adopted cooperative strategies to address the common pool resource problems of groundwater extraction. Based on their age old experience, a few farmers have reported that there were years of extreme drought leading to severe failure of the pumpsets in delivering water.

5.1.13 Groundwater Application and Rules for Distribution of Water among the Buyers:

The farmers, in the study area, have adopted High Yielding Variety (HYV) seeds of the crop. In general, the growing season for any variety is 120 to 150 days. The preferred planting method is transplanting of seedling using wet bed technique. Under this technique, after preparation of the land, the 25-40 day old seedlings are transplanted in the field. Irrigation starts from the very beginning of the land being prepared for plantation, as the cultivation of the crop is taken up in the dry season when rainfall is almost zero. During initial days for ploughing, a larger amount of water is required. On an average, water is applied for 12 numbers in the crop fields during the whole season.

Regarding application of water in farmer's field, the common phenomenon in the water market is that a water seller applies more water consistently than that of the water buyers as the market is residual in nature i.e. a water buyer gets water only after the fulfillment of the requirements of the tubewell owner-cum-sellers. However, in the study area, no such great deal of difference between buyers and sellers in the number of application of water in the crop fields has been noticed. While the average number of irrigation on a seller's plots is found to be 14 numbers, the same on buyers' plots has been found to be 11 numbers during the whole season.

As discussed in section 5.3.1, about 25.78 percent of the sample buyers have bought water from multiple buyers. At the same time, a sample water seller is found to have

3.6 number of buyers under him. For distribution of water among the buyers, a rotation method is practised. However, there is no concrete rotational period. In some sample villages, while a 3 day rotation method has been observed, in some cases farmers have to wait for more than 7 days depending on the number of buyers of a seller. The water sellers have been found to be stricter in maintaining this rotational system to avoid conflict among the buyers. The buyers failing to be present in their turn are refused water and required to wait till the end of the cycle. Many sample buyers have complained of preferential treatment practised by the sellers in delivering water in terms of giving importance to some of the buyers who are mostly relatives of the sellers. However, most of the buyers are in favour of the rotational water delivery system as they have found it to be an equitable system for water distribution. It has been noticed that buyers are also required to supervise the operation of the pumpset and water distribution, for which they are not paid.

5.2 Tubewell Characteristics and Operation of the Groundwater Market:

Since, the groundwater market takes place around a shallow tubewell, it is imperative to look at the characteristics of the tubewell and their link with the mode of operation of the market. Therefore, in this section an attempt is made to look at the characteristics of the tubewells owned by the sample farmers under different categories of market participants. The general characteristics of the tubewells, owned by the sample farmers, are presented in Table 5.9. The data furnished in Table 5.9, have been discussed in the relevant sub-sections under this section.

Table 5.9
General Characteristics of Shallow Tubewells

Description	Figures
Modal size of diesel pumpset (hp)	5
Modal size of electric motors (hp)	2
Average number of tubewells owned by the sample farmers	1.39
Modal size of boring (cm)	4
Frequency of only diesel operated tubewell (%)	74.79
Frequency of only electric motor operated tubewell (%)	6.72
Frequency of both diesel and electric motor operated tubewell	18.49
Modal number of boring of tubewell owners	1
Average number of boring of tubewell owners	1.44
Average depth of boring (in feet)	67.46
Average distance from the nearest tubewells (meter)	168.74

5.2.1 Types and Ownership of the Tubewells:

There are 119 sample farmers who own tubewells. Out of these total sample farmers, about 95.80 percent farmers own tubewell individually and the rest 4.20 percent have joint ownership. Normally, a farmer prefers individual ownership in order to gain control over irrigation. In case of joint ownership, there is a group of farmers sharing contiguous plots and consisting of relatives, neighbours and friends who contribute resources to install a tubewell.

A few sample owners of tubewells have been found to own more than one pumpset. While about 20.35 percent of the tubewell owners have owned two pumpsets, about 29.20 percent of the sample owners have owned more than two pumpsets. It has been found that most of the pumpsets (about 78.79 percent) were procured by the farmers 10 years back. Only about 19.45 percent of the pumpsets are procured recently in the last five years. However, some operational pumpset were bought about 20 years back. Farmers having pumpsets which were procured 20 years back and they are still used in water selling activities. Thus, it can be inferred that the groundwater transaction in the sample villages has been in vogue for more than two decades.

Over the years, there has been a change in the types of fuel used in the pumpsets used for irrigating field. While the older tubewells are mostly operated with the help of diesel, there is an increasing tendency to use electricity in the newly installed tubewells. The shift from the diesel operated pumpsets to electric powered pumpsets is mainly due to cheaper maintenance and operational costs of the electric motors. The maintenance cost of a pumpset is the expenditure made in order to prevent or fix any sort of mechanical disorder to keep the pumpsets in working order. The operational cost of a pumpset is the cost of power or fuel used in running the pumpset in order to irrigate the land. While average maintenance cost of a diesel tubewell is found to be about ₹ 1,923.71 per pumpset, the same for electric tubewells is almost zero. The maintenance cost for electricity operated tubewells of the sample farmers has been found to be zero as they have been procured recently. The operational cost of a diesel tubewell is about ₹ 8, 705.29 per hectare across all categories of participants of water market. The same for electrical tubewells are ₹ 6, 033.55 across the sample farmers (the average operational cost of electric tubewells without commercial connection is found to be ₹ 3101.30). Moreover, as reported in section 5.1.11, fluctuating price of diesel has also resulted in

higher preference for electric pumpsets. Also, the initial investment for an electric motor is found to be much lower compared to diesel pumpsets. Further, farmers prefer electricity operated STWs because a new electric motor commonly preferred by sample farmers, requires a maximum of ₹ 20,333.33 whereas a new diesel pumpset costs a maximum of ₹ 28,100.00. The difference in the average prices of a pumpset is found to be up to 30.34 percent of the electric pumpsets. There is also the practice of purchase and sale of second hand pumpsets in the study area.

Despite the relative advantages of owning electricity operated tubewells over diesel tubewells, the inadequate and erratic supply of electricity in the sample villages has constrained speedy adoption and diffusion of electricity operated tubewell technology. This is unlike the situation in some states in India where in response to rapid rural electrification, cheaper institutional credit and technological advances in groundwater pumping electrical pumpsets have rapidly replaced diesel-powered lifting devices (Ray, 1998).

5.2.2 Capital and Operating Expenditure of a Tubewell:

Expenditure incurred on owning a tubewell either diesel or electricity operated tubewell is shown in Table 5.10.

It is clear from Table 5.10 that the maximum expenditure that a diesel tubewell entails is ₹ 28, 100.00 when the pumpset is a brand new. Price also varies depending upon capacity of the tubewell. The average price of diesel tubewell (₹ 11,016.99) has been found to be very low as there is an active market for second hand diesel operated pumpsets.

Table 5.10
Expenditure Incurred on Owning, Installation, Operating and Maintaining the Tubewells

Items of expenditure	Maximum	Average
Capital outlay per diesel pumpset (in Rs.)	28100.00	11016.97*
Capital outlay per electric motor (in Rs.)	20333.33	8452.47
Capital outlay on equipments per machine (in Rs.)**	11000.00	2957.01
Labour charge on installation of borings (in Rs.)	10000.00	1529.58
Operational cost of diesel tubewell for the whole season (in Rs./ha)	18836.84	8705.29
Operational cost of electric tubewell for the whole season (in Rs./hectare)***	25912.00	6033.55
Repairing and maintenance of diesel tubewell in the season (in Rs./per pumpset)	5000.00	1923.76

Notes: *Includes used pumpsets as many tubewell owners have purchased used pumpsets.

** Equipments of diesel tubewell includes bearing pipe, filter net, delivery pipe, L-socket, T-socket, Hand pump *munda* (it's the local name for the handle used to run a pumpset).

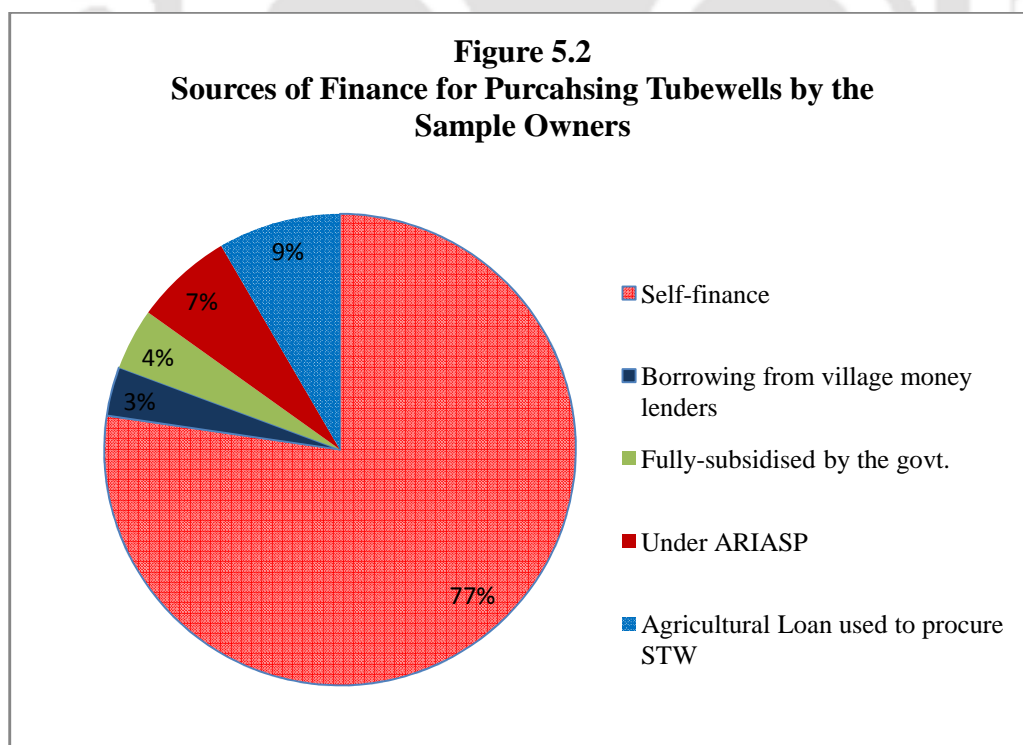
*** without commercial connections it is found to be ₹ 3101.301).

The electricity operated tubewell costs a maximum of ₹ 20,016.33 for electric motor with 3 or more than 3 hp capacities. An electric motor of 3 hp capacity is the maximum capacity of an electric motor used by the sample farmers. Since majority of the farmers possess electric motor with capacity of 1.5 hp, the average price has been found to be ₹ 4,500.00 only. On the average, the equipments required to install either an electric or diesel tubewell costs a sum of ₹ 2,957.00. There is also a variation in total expenses incurred in buying equipments depending on quality of the items purchased. Labour charge for installation of boring is generally in the range of ₹ 65.60/- to ₹ 98.40/- per meter resulting in the average expenditure of ₹ 1,529/- on labour charges. It is evident from Table 5.10 that, on the average, the operational cost of diesel tubewell is higher than the electricity tubewell. It is mainly due to the fact that the incremental cost of a diesel operated tubewell is found to be higher than the incremental cost of electricity operated tubewell which is almost zero due to fixed electricity charge. However, this is not the situation when the consumption of electricity of an electricity operated tubewell is monitored by electric meters. But the presence of electric meter system is very few. Moreover, it is to be noted that electricity operated pumps are operated on unauthorised manner. The farmers have no commercial electricity connections for operating the electric motors. As the operational cost of electricity operated tubewells is lower than

the diesel operated tubewells, it has been observed that buyers tend to prefer the former. Further, the mode of operation of the market is such that the buyers are required to pay for the diesel in operating the pumpsets, which most of the time a resource poor farmer find it difficult to afford. As a result, there is also a general tendency among the buyers to look for electricity operated pumpsets when they are available near their crop field. Further, while the annual maintenance cost of the sample electric motors have been found to be almost zero, the same for the sample diesel pumpset, on the average, has been found to be ₹ 1923.76.

5.2.3 Financing of Tubewell:

As discussed in the preceding section, it has been found that majority of the tubewells are privately or individually owned. Unlike the case in previous studies of water market which have reported that ownership of tubewell is skewed towards large and wealthy farmers, in our sample it has been found that the majority of the sample tubewells owners, about 63.86 percent, belong to small and marginal categories. . The sources of finance for purchasing tubewells include own savings, borrowing from village moneylenders, agricultural loan, etc. The details are provided in Figure 5.2.



It has been found that a majority of sample tubewell owners, about 77.31 percent, have procured the tubewell through their own savings. Out of the rest, about 4.20 percent have availed the tubewell under different government schemes with full subsidy and about 6.72 percent have procured the pumpsets under ARIASP schemes of the government. Under the ARIASP, a two third of the total cost of a pumpset is provided by the government as subsidy. Around 8.40 percent of the tubewell owners have spent a part of their agricultural loan on purchasing pumpsets. Owing to constraint towards access to credit from institutional sources, around 3.36 percent have relied solely upon the village money lenders for credit. A few sample farmers, about 21.84 percent, rely upon credit from village money lenders to meet operational cost of the pumpsets and sometimes to meet a part of the maintenance expenditure of the pumpsets too.

5.2.4 Tubewell Density among the Sample Farmers:

There are altogether 185 tubewells including both diesel operated pumpsets and electricity powered pumpset, among 119 sample tubewell owners. Out of the total sample owners, about 81.51 percent are engaged in water selling. The total number of present buyers, who purchase water from these sellers, are 354. This indicates that one tubewell serves 2.55 number of farmers including owners, sellers and buyers.

5.2.5 The Capacity of the Tubewells:

The capacity of the most commonly used diesel operated tubewells is in the range of 4 hp to 10 hp. However, the 5-hp diesel operated tubewell is found to be the most common. About 84.86 percent of the farmers have been found to be using 5-hp diesel operated tubewells. A 5-hp diesel operated tubewell has the potential of irrigating 2.01 hectare of land in the state when they are used at the fullest capacity (NABARD, 2008). However, in the present study, the average area irrigated from a 5-hp diesel STW is found to be 1.09 hectares implying under utilisation of the installed capacity of the tubewell.

The capacity of the most commonly used electric tubewells has been found to be in the range of 1.5 hp to 3 hp. About 54.75 percent of the owners of electric pumpsets use 2 hp electric motors. A 2-hp electric powered tubewell has the potential of irrigating 2.67 hectare of land when they are used at the fullest capacity. The owners of electricity

operated tubewell has been found to be possessing only one electric motor. Only about 6.45 percent of the owners of electric motors have more than one electric motor.

5.2.6 The Energy or Power Consumption:

Supply of energy, in terms of electricity and diesel for pumping, plays an important role in the operation of the market. This is linked with reliability of the groundwater markets in ensuring timely supply of water to owner's as well as on the purchased land. About 84.86 percent of the sample tubewells are diesel powered while the rest are electric powered. In the wake of high operational cost of a diesel operated tubewell, as high as 78.15 percent of tubewell owners have expressed their preference for electricity operated tubewells over diesel operated tubewells. . However, due to erratic electricity supply, the sample farmers have a general tendency to rely on diesel pumpsets to ensure assured irrigation. As a consequence, groundwater irrigation has become increasingly dependent upon costly diesel fuel. The higher diesel price has also forced many sample farmers to drastically reduce their cultivable area under summer rice which is mainly based on groundwater irrigation. As discussed in section 5.2.11 of this chapter, owing to increased operational cost of pumping of a diesel operated pumpset, about 36.85 percent of the sellers, reported that the number of buyers have been declining over the years. However, no sample tubewell owners have given up groundwater pumping owing to increased diesel prices. It has been found that the electricity tariff is not metered (in majority of the cases), but is fixed on an annual basis irrespective of hours of usage. It indicates that the marginal cost of pumping is effectively zero or very near to zero like the one mentioned by Shah (1993), Kajisa and Sakurai (1995), Banerji et al. (2006), etc. This has provided the owners of electric tubewells an additional incentive to sell water to more prospective buyers.

5.2.7 Characteristics of Boring:

In the context of the groundwater market, the characteristics of the boring of a tubewell assume significance as they affect availability of water for selling and reliability of the market considerably (Meinzen-Dick, 1998; Khair et al., 2012). In the present study, the majority of the sample tubewell owners (73.10 percent) have been found to have a single boring. The rest of the tubewell owners have multiple borings mostly when cultivated lands are fragmented. However, the total number of borings (172 numbers) is

found to be lesser than the total number of pumpsets. There is also the incidence of farmers renting in the pumpsets and extracting water from the boring on own land and selling it to others. This suggests presence of rental markets for irrigation assets like the one indicated by Saleth (1998). Regarding characteristics of a boring, the modal value of diameter of a boring is found to be 10 cm and the average depth of a boring is found to be 20.50 meter. A difference of up to 64.48 percent in the average depth of the boring has been noticed in a few sample villages lying relatively in high land.

The depth of boring has an important implication in terms of cost of operation of a pumpset. In the face of increased operational cost of a diesel pumpset reported by the majority of sample seller and buyers, it is imperative to look at how depth of a boring can affect operational cost of a diesel operated pumpset. In order to ascertain this point, the operational cost of a diesel tubewell per hectare of land, is regressed to the “depth of boring” of the respective farmer (denoted in short as DPTHB). Since, operational cost of a pumpset is also influenced by the number of times of irrigation in a crop field, therefore, ‘the total number of irrigation’ (denoted in short as TNIRRI) applied by the farmer in the crop fields has also been included as a regressor. The results of the regression model are presented in Table 5.11.

Table 5.11
Results of Regression Analysis of Operational Cost of a Diesel Pumpset of the Sample Farmers

Variables	Coefficients	Standard Error
Constant	2746.09**	1291.58
TNIRRI	142.97*	85.82
DPTHB	62.09***	9.52
R ²	0.247	
F (df =2, n = 135)	22.25***	

Notes: ***, ** and * signify significance 0.01, 0.05 and 0.10 levels.

It is evident from table 5.11 that though the value of R² is not high, the F- statistic for overall regression and the coefficients of the variables are found to be statistically significant. The positive sign of the coefficient of TNIRRI indicate that higher the number of irrigation, larger is the operational cost. Similarly, the sign of the coefficient of DPTHB is positive indicating that higher the depth of the boring, larger is the

operational cost. To be very precise, when depth of boring of a pumpset increases by one unit, it leads to increase in the operational cost of a diesel powered tubewell by ₹ 62.09 per hectare.

5.2.8 Water Conveyance:

As explained in the introductory section of this chapter, the presence of water market is contingent upon availability of willing buyers within the command area of the tubewells when the pumpset is fixed (Pant, 1992). In conformity with this, it has been found that about 88.65 percent of the sample sellers have sold water to the buyers who have plots adjacent to the sellers. However, a small section of the sellers (about 11.35 percent) are found to sell water to the buyers whose plots are located a little away from the source of irrigation. In such a situation, the buyers have to arrange for conveyance facilities for conveying irrigation water from the source. It has been found that both earthen channels and polyvinyl chloride (PVC) plastic pipes are used by the buyers for conveying irrigation water to the field. However, provision of earthen water channels is available when buyers are tenants of the water sellers. In the rest of the cases, buyers have been found to use PVC pipe. Buyers normally prefer plastic pipe as it helps in avoiding conveyance loss. If the plots of the second seller is available in between the seller's plots and the farmer's plots, conveyance facilities through the second seller's plots is normally not permitted. This, as Jacoby et al. (2004) and Hussain et al. (2005) have pointed out, has limited the expansion of the market thereby restricting farmers' access to irrigation and degree of competition in the market.

5.3 Production System across Different Participants of the Groundwater Market:

Looking at the production system of the sample farmers, by their status in groundwater market, is important as it bears serious implication on the level of attainment of technical efficiency of the farms. The basic characteristics of the production system across different categories of groundwater users are discussed in the following subsections.

5.3.1 Types of Operation:

The majority of the sample farms (92.19 percent) are under single operation. There are only 13 cases where farming is done jointly with other families which are mostly the

relatives. The head of the household, normally the oldest man in the family, takes major decision relating to farming.

5.3.2 Use of High Yielding Variety (HYV) Seeds:

Since availability of irrigation water is ensured, the use of HYV seeds is universal in the study area. The varieties which are found to be popular among sample farmers are: *No. 9, No 29, Bihari, Biplab, Cross, Pankaj, Mahsuri, Arize 6444, ITC, Advanta, Jaya, Bahadur, Bangla, Param, Sonai, Zero 29, Mihir, Ranjit*. While some of the HYV seeds have been used by the farmers for quite some time now, a few new varieties have been introduced in the study area in 2012. About 85.86 percent farmers have been cultivating old varieties and the rest 10.99 percent have been using new varieties of the crop.

5.3.3 Extent of Farm Mechanisation:

The process of farm mechanisation involves application of farm inputs by using power driven agricultural equipments. Mechanisation is necessary for various operations involved in crop production like threshing, processing, transportation, value-addition, storage, etc. Farm mechanisation ensures reduction of drudgery associated with various farm operations, economises utilisation of inputs and enhances productivity and production. These, in turn, help in harnessing the full potential of input bundles applied in cultivation.

The process of mechanisation may take place with the help of either own machines or hired. It has been found that among the 191 sample farm units, about 2 percent own tractor, about 8.6 percent own power tiller, around 52 percent poses bullocks, 39.4 percent have sprayer and around 2 percent have harvester.

The extent of farm mechanisation among the sample farms under different structures of the market is presented in Table 5.12.

It is evident from Table 5.12 that there is no significant difference in case of farm mechanisation between water sellers and buyers. Among all the activities, the use of machine is the highest in ploughing. While about 59.49 percent of the buyers have used tractor or power tiller for ploughing the crop field, about 68.75 percent of the “self-users+sellers” have used the same in ploughing. This is followed by spraying where

about 40.18 percent of the “self-users+sellers” and about 43.03 percent of the buyers have used the powered spraying. Use of machines in harvesting and threshing is lower for all the categories of farmers under consideration. It has a serious implication for the viability and sustainability of summer rice cultivation in the study area. The harvesting period of summer rice coincides with high rainfall and early flood (in most of the years) making the process of harvesting and threshing more difficult for the farmers. Therefore, the post harvest handling of summer rice, viz. threshing, drying and milling or selling has to be improved introducing some innovative measures.

Table 5.12
Extent of Farm Mechanisation among Buyers and Sellers

Areas of mechanisation	Self-users, self-user+sellers, self-users+sellers+buyers, self-users+buyers*			Only buyers		
	Non-power	Power	both power and non-power	Non-power	Power	both power and non-power
Ploughing	31 (27.68)	77 (68.75)	4 (3.57)	32 (40.51)	28 (35.44)	19 (24.05)
Leveling and Harrowing	94 (83.93)	18 (16.07)	-	67 (84.81)	12 (15.19)	-
Puddling	80 (71.43)	19 (16.96)	4 (3.57)	62 (78.48)	14 (17.72)	3 (3.80)
Bund making	108 (96.43)	4 (3.57)	-	78 (98.73)	1 (1.27)	-
Plantation	109 (97.32)	3 (2.68)	-	78 (98.73)	1 (1.27)	-
Transplanting	109 (97.32)	3 (2.68)	-	77 (97.47)	2 (2.53)	-
Fertiliser use	108 (96.43)	4 (3.57)	-	77 (97.47)	2 (2.53)	-
Weeding	98 (87.50)	14 (12.50)	-	79 (100)	0	-
Spraying	67 (59.82)	45 (40.18)	-	45 (56.96)	34 (43.04)	-
Harvesting	104 (92.86)	8 (7.14)	-	76 (96.20)	3 (3.80)	-
Threshing	81 (72.32)	31 (27.68)	-	71 (89.87)	8 (10.13)	-

Notes: *Tubewell owners, engaged in water sale but do not cultivate the crop, are excluded.

5.3.4 Use of Soil Nutrients:

The increase in area under summer rice as a result of adoption of STWs by the farmers has led to a noticeable increase in consumption of fertilisers in Assam (Govt. of Assam, 2013b). Consumption of fertiliser in the state has increased from 12.48 kg/hectare in 1995-96 to 27.66 kg/hectare in 1999-2000. The figure went up to 49.50 kg/hectare in 2003-04 and then to 67.09 kg./hectare in 2010-2011. However, rate of fertiliser use is far below the average for the country as a whole. The amount of fertiliser consumption of the sample farms are presented in Table 5.13.

Table 5.13
Amount of Fertiliser Consumption of the Sample Farms

Types of fertilisers	All farmers			Self-users, self-user+sellers, self-users+sellers+buyers, self-users+buyers*			Buyers		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
N+P+K (kg/ha)	6.30	362.50	162.95	7.80	362.50	163.78	6.30	350.50	161.82
Organic Manure (kg/ha)	0.75	156.97	16.81	1.07	156.97	19.02	4.98	66.44	15.83
Micronutrient (g/ha)	4.27	3449.95	410.01	4.27	1121.24	205.61	7.47	3449.95	639.21

It is clear from Table 5.13 that the consumption of fertiliser of the sample farms is very high. The average fertiliser (N+P+K) consumption rate is 162.95 kg per hectare for all the farmers which are marginally greater than the amount prescribed by the Department of Agriculture of Government of Assam (which is 161 kg/hectare) for the cultivation of summer rice. However, there is a great amount of difference between the maximum and minimum amount of Consumption of fertiliser by the sample farms. There are differences in the rate of fertiliser consumption between water “buyers” and “self-user+sellers”. The table also shows that on the average, sellers tend to use higher doses of fertiliser than those of the buyers. While the average consumption of fertiliser is 161.82 kg/hectare for the buyers, the same is 163.78 kg/hectare for the sellers. In the literature of water market, most of the studies point out that “self-user+sellers” tend to use more fertiliser as they are financially capable. The finding of our study confirms it as the “self-user+sellers” are found to be using more fertiliser, on the average, than the “buyers”.

The high amount of fertiliser consumption in the sample area is to be expected as the sample includes only irrigated farms. It has been found that the sample farmers have a tendency to use more doses of fertiliser in cultivation of summer rice believing that more application of fertiliser would increase production.

The amount of fertiliser consumption also differs depending upon farmers' adoption of different varieties of HYV seeds. The amount of fertiliser consumption across different varieties of the crop is presented in Table 5.14.

Table 5.14
Amount of Fertiliser Consumption of the Sample Farms under New and Old HYV Seeds

Types of fertiliser	New varieties of HYV seeds			Old varieties of HYV seeds		
	Minimum	Maximum	Average	Minimum	Maximum	Average
N+P+K (kg/ha)	7.80	362.50	165.98	6.30	249.20	137.06
Organic Manure (kg/ha)	7.47	37.37	18.55	.75	156.97	16.47
Micronutrient (g/ha)	7.47	1121.24	426.65	4.27	3449.95	403.57

It is evident from Table 5.14 that there are large differences in the amount of fertiliser consumption among sample farms using old and new varieties of HYV seeds. On the average, new varieties of HYV seeds tend to use more doses of fertiliser than the old varieties. While the rate of fertiliser consumption is 165.98 kg/hectare in case of new varieties of HYV, the same is 137.06 kg/hectare in case of old varieties. In addition to use of chemical fertiliser, the sample farmers have been found to be applying micro-nutrients and organic manure in order to improve soil quality.

In the study area, though the farmers are found to have some basic knowledge about the use of chemical fertilisers, pesticides, etc.; they lack scientific knowledge on proper use of fertilisers. Usually, the sample farmers apply same dose of chemical fertiliser as what their peer neighbouring farmer does. Most of the farmers have reported that they do not get the required support and guidance from the Department of Agriculture in these respects.

5.3.5 Yield of Summer Rice:

The Gross Cropped Area (GCA) for all sample farm units (191) is found to be 180.69 hectare. The total output from the GCA is found to be 12,447.58 quintals. Thus, the average yield of summer rice for all farm units is found to be 68.89 quintal/hectare. While the farms adopting old varieties of HYV seeds have recorded average yield of 68.18 quintal/hectare, the farms adopting new HYV seeds have recorded relatively much higher yield of 81.45 quintal/hectare.

There is variation in yield of the crop among different categories of participants of water market. This variation is found to be in the range of 66.44 quintal/hectare to 75.27 quintal/hectare across different categories of farmers. The yield of summer rice to different participants of water markets is presented in Table 5.15.

It is evident from Table 5.15 that there is hardly any difference in the average yield of the crop between “self-users” and “self-users+sellers”. The category “self-users+sellers+buyers” has registered the highest yield of 75.27 quintal/hectare among all the categories. While “self-users+buyers” have realised an average yield of 68.78 quintal/hectare, the “buyers” have registered the lowest yield of 66.44 quintal/hectare among all the categories.

Table 5.15
Yield of Summer Rice across Different Categories of Participants of Groundwater Market

Category	Yield per hectare (in quintal)		
	Minimum	Maximum	Mean
Self-users	29.90	99.66	70.29
Self-users + sellers	38.87	95.25	70.57
Self-users + sellers +buyers	51.64	152.15	75.27
Self-users + buyers	44.85	107.64	68.78
Buyers	35.88	89.70	66.44

5.3.6 Farmer’s Contact with the Extension Agencies:

Extension work has been an important factor in the diffusion of improved agricultural practices among farmers (Dutta, 2011). Therefore, in the schedule administered in the

field, questions were included to record the influence of government extension agencies on the farming practices of the sample farmers. The farmers' responses to these queries have been codified and scores awarded. On the basis of the scores, the level of contact with extension agencies have been categorised into i) very good, ii) good, iii) moderate and iv) poor. (The details of codification process and the score system are reported in Appendix-5.1).

The distribution of sample farmers under different market structures, according to the level of contact with extension agencies is shown in Table 5.16. The table shows that only about 23.70 percent and about 5.60 percent of the sample farmers have good and very good contact with the extension agencies respectively. This indicates that about one fourth of the total farmers have benefited from the service of the government. About 47.50 percent of the total sample farmers are not even aware of the personnel of extension agencies for their respective area. The rest 23.70 percent of the sample farmers, although knew the personnel, have not received any direct benefit from the extension service. Thus, on the whole, the sample farmers have not received better extension services.

Table 5.16
Distribution of Sample Farmers under Different Market Structure According to the Level of Contact with Extension Agencies

Category of extension services	Category of participants in the water market						Total
	Self-users	Self-users + sellers	Self-users + sellers + buyers	Self-users + buyers	Buyers	Owner + sellers	
Poor	8 (44.44)	28 (36.48)	10 (71.43)	1 (25.00)	46 (58.23)	1 (14.29)	94 (47.50)
Moderate	4 (22.22)	17 (22.37)	3 (21.43)	2 (50.00)	18 (22.78)	3 (42.86)	47 (23.70)
Good	4 (22.22)	25 (32.89)	1 (7.14)	1 (25.00)	13 (16.46)	2 (28.57)	46 (23.20)
Very Good	2 (11.11)	6 (7.89)	-	-	2 (2.53)	1 (14.29)	11 (5.60)
Total	18	76	14	4	79	7	198 (100)

Notes: Figures in parentheses indicate percentage to the column total.

The table shows that compared to the sample “buyers”, the “self-user+sellers” have better contact with the extension agencies. About 40.78 percent of the sample “self-users+sellers” have good or very good contact with the extension agencies and are also benefited from the service. Compared to this, only about 19 percent of the sample buyers have good and very good contact with the extension agencies.

5.4 Other Aspects of Production and the Groundwater Market:

5.4.1 Access to Credit:

Access to institutional credit is important for a farmer as it helps in technological adoption leading to overall agricultural growth. Though some available technologies are scale neutral, but they entail cost. As such small and marginal farmers, often find it difficult to procure certain types of technologies which require large initial investment. In such a situation, farmers’ access to institutional credit enables them to procure modern technologies. However, in many developing countries, particularly in rural areas, access to credit is highly limited (Ray, 1998). In areas, where financial services are available, they are often not accessible for the marginal and small farmers especially due to lack of required collateral. As a result, farmers often face high interest rate and unfavourable borrowing conditions from the village money lenders (Ray, 1998).

In the context of the present study, a farmer’s access to credit is important because of its significant role in the operation of groundwater market. Farmers who are not capable of installing any tubewell on their own and who turn out as water buyers, have cited lack of access to credit as one of the fundamental reasons for not being able to buy a pumpset. Unavailability of credit also has restricted the farmers in owing capital goods and other modern technologies. Access of the sample farmers to financial services is presented in Table 5.17.

It is evident from Table 5.17 that about 25 percent of the farmers have their savings account either in commercial banks (22.70 percent), post offices (16.20 percent) and other private agencies (15.20 percent). About 22.20 percent of the sample farmers have life insurance policies. Only about 24.24 percent of the sample farmers have availed agricultural loan, known as Kisan Credit Card (KCC), from the commercial banks.

This shows that the sample farmers have a very limited access to institutional finance in general and institutional credit in particular. Their need for credit is still fulfilled by village money lenders against a high interest rate. Farmers have reported that they need to pay interest rate as high as 10 to 13 percent per month for a period of six months which is dramatically higher than 12 percent per annum charged by the formal banks.

Table 5.17
Access of Sample Farmers to Financial Services/Institutional Credit

Types	Nos. of farmer
Savings in the commercial banks	45 (22.70)
Savings in the post offices	32 (16.20)
Savings in the private agencies	30 (15.20)
Possession of Life Insurance Policies	44 (22.20)
Agricultural Loan	48 (24.24)
Loan from Self-help Groups (SHG)	28 (22.00)*

Note: Figures in parentheses indicate percentage of the total sample farmers except the case for SHG where the percentage in parentheses refers to out of the total of 133 who are members of the SHG.

The distribution of sample farmers, under different categories of market participants, having access to institutional credit is presented in Table 5.18.

Table 5.18
Distribution of Participants of Groundwater Markets
According to their Access to Institutional credit

Category	Nos. of farmer
Self-users	2 (4.17)
Self-users + Sellers	27 (56.25)
Self-users + Sellers + Buyers	6 (12.50)
Self-users + buyers	2 (4.17)
Buyers	11 (22.92)
Owner + Sellers	0
Total	48 (100)

Note: Figures in parentheses indicate percentage of column total.

It is evident from Table 5.18 that out of the total sample farmers having access to formal agricultural credit, the majority of them (about 77.02 percent) are “self-users+sellers”. A sizeable number of sample farm households (66.20 percent) are members of SHGs. About 22 percent of the sample farms also have taken loan from their respective SHGs to meet expenses of farming. A few farmers have been found to be taking loan from the SHGs to meet operational cost of the pumpsets.

5.4.2 Labour Employment:

Agriculture, which is relatively less modernised, uses more labour. In the study area, two types of labour have been found: family labour and hired labour. Family labours are the members of any farm family engaged in cultivation throughout the season both full time or part time. Hired labours are those hired to assist in cultivation. They are of two types: labour who generally work on seasonal basis and they work on some sort of contract. The area rate approach is mostly followed while determining their wage. On the other hand, temporary or casual hired labours are engaged only during peak period for work. Their employment is temporary and they are paid at the prevalent market rate. The total labour (measured in mandays) employment made by the sample farm is presented in Table 5.19.

It is evident from Table 5.19 that the sample farm units have generated 22, 437 labours (measured in mandays) in the whole season. Out of this total employment, about 67.54 percent are hired labour. The average number of labour mandays required per farm, in the whole season is found to be 79.34 labour mandays, which is almost double the total numbers of family labour.

Table 5.19
Total Labour (measured in mandays) Employment by the Sample Farms

Types	Numbers
Total family labour	7,282 (32.45)
Total hired labour	15155 (67.54)
Total labour (family labour+hired labour)	22437 (100)

Note: Figures in parentheses represent percentage to column total.

Many sample farmers have reported that there is labour shortage during the peak season especially during harvesting time. As a result, there are situations where labour has been brought from other districts of the state. These groups of hired labour work on contractual basis and charge about 14.98 quintals per hectare. It is also noticed that labour payment constitutes a major share of the total cost incurred in the cultivation of the crop. In addition, the discussion with a few respondents also reveals that due to this seasonal labour shortage, many farmers have reduced area under the cultivation of summer rice. Besides, many water sellers also have reported that numbers of buyers are going down as they have not been able to meet the expenditure incurred in cultivation due to this seasonal labour shortage. It indicates that labour shortage has appeared to be a major problem in agriculture sector in rural areas.

5.5 Summing Up:

This chapter discusses the nature, structure and functioning of groundwater market, the general characteristics of the tubewells and the basic characteristics of the underlying production system based on primary data collected from the field. It is clear from the above discussion that groundwater market in the study area mostly resembles the same pattern of operation as is observed in other Asian countries like Pakistan, Nepal, Bangladesh and China and many parts of India. There is no formal rule governing access to groundwater among the farmers. Groundwater has been found to be treated as a *de-facto* open access resource as the owners of land consider it as their private property. This makes the market informal. It has been found that the farmers coming from the same village and work in the same crop field or coming from different villages but work in the same crop field, are engaged in water transaction. The groundwater market is found to be localised in nature as Shah (1993) termed it, as the water transaction is constrained by limited availability of conveyance facilities. Six alternative forms of arrangement for groundwater use have been observed. In contrast to the existing literature on the operation of the water market, about 5.88 percent of the total sample tubewell owners possess a tubewell only for selling groundwater. This indicates that groundwater market has helped a few farmers to take up groundwater pumping as an additional source of income. It also suggests that the market is not residual to all the buyers. The majority of the buyers are found to be marginal and small farmers. This is in line with the findings of almost all studies on water market which

state that water buyers are usually small and marginal farmers. The size-wise analysis explicitly shows that when farm size increases the number of buyers decreases. More than 65.98 percent of the water sellers belong to the marginal and small farmers' category and it has been found that the number of sellers has decreased with increase in the farm size holding. This is a deviation from the established theory in the literature of water market that water sellers are larger and wealthy farmers. The study has rather identified that when farm size increases the number of buyer decreases but the reverse is not always true for the sellers. The study also finds that with more availability of conveyance facilities the market can be expanded to reach more willing buyers though they are not the immediate neighbours of any water seller. This, in turn, will help achieving better utilisation of the capacity of the installed tubewells. Water transaction has been found to be taking place in both cash and kind, with latter dominating the scenario. Water transaction has also been found to be influenced by the presence of personal relationship between buyers and sellers. Other non-economic factors like caste, religion, etc. has no role in the operation of the market in the study area unlike some other studies on water market in the eastern part of India. Buyers have also been required to render some other services to the sellers to ensure reliability of water supply when required. Most of the water buyers are found to be the tenants of the sellers indicating that the market is interlocked with the existing land tenure system. Water charges have been found to be almost uniform within a village, though a few sample buyers have been provided concession by the sellers. Most of the sellers cite that labour shortage, steep rise in input prices; particularly fertilisers and inadequate procurement price for the crops are among the factors that have compelled some of the buyers to give up cultivation resulting in net reduction in market transaction over the years. The discussion on the characteristics of tubewells shows that majority of the tubewells are diesel operated though there is a gradual shift towards the electrical pumpsets. This is due to lower operational and maintenance cost of electricity operated tubewells and fluctuating prices of diesel. However, the adoption of electricity operated tubewells is constrained by absence of electricity connections in a few places, and inadequate and erratic supply in places where the electricity connections are available. Results of the production system show that there are differences in input use, level of contact with the extension agencies and extent of farm mechanisation between tubewell owners-cum-sellers and the buyers indicating a serious implication in the attainment of technical

efficiency of the farms. A significant difference is also noticed in yield of the crop between plots of sellers and buyers.

However, the discussion on this chapter could not specifically identify the factors that may enable a farmer to own tubewell and sell groundwater to needy farmers. Similarly, factors that influence a farmer to buy water have also not been specifically clear from the above discussion. Therefore, an investigation into the determinants of tubewell ownership along with their relative significance and the factors that enter groundwater buying or selling decisions is required. The next chapter is an attempt to discuss the determinants of groundwater markets in the study area.

Notes:

1. Crop failure mainly takes place due to flood with early monsoon as the field study locations of both the districts lie in the low lying areas.
2. This term was coined by Dubash (2000) in his paper “ Ecologically and Socially Embedded Exchange: 'Gujarat Model' of Water Markets” *Economic and Political Weekly*, Vol. 35, No. 16 (Apr. 15-21, 2000), pp. 1376-1385
3. For details see Saleth (1998), pp. 194-95.
4. Monopoly power is related to price. But in the literature of water market this is explained based on the degree of exploitation exercised by the water sellers on the buyers through different means as delineated in the section.

Appendix – 5.1

Details of Classification Procedure and Score System for Farmer's Contact with Extension Services

The following questions were asked to know the extent of farmers' direct contact with the government agencies:

- a) Do you know the VLEW of your village?
Yes (1)/ No (0)
(If the answer is No proceed to e)
- b. Have you met him in the last seven days?
i. in the last seven days (3)
ii. within one month (2)
iii. over one month (1)
iv. can't remember (0)
- b) Have you consulted him on farming problems recently?
Yes (1)/ No (0)
- c) Have you followed his advice?
i) Did not follow (0).
ii) Followed but found useless (1)
iii) Followed and found useful (2)
- d) Do you know the AEO of your area?
Yes (1)/ No (0)
- e) Did he visit your village during the last three months?
Yes (1)/ No (0)

Figures in the parentheses represent respective code. On the basis of score, four classes were categorised as follows:

- 1) Very good – score 9
- 2) Good – score 4 to 8
- 3) Moderate – score 1 and 4
(No help received but knew VLEW/AEO)

Poor – score 0 (Did not know VLEW/AEO)



CHAPTER SIX

DETERMINANTS OF GROUNDWATER MARKET

In chapter five, a detailed discussion on the nature, structure and functioning of the groundwater market and its interlinkage with other rural markets in the study area, has been made. It has been found that there is an increasing tendency among the sample farmers towards owning a tubewell to gain control over irrigation. Under such circumstances, it is worthwhile to explore the factors that enable a farmer to own a tubewell and then what induces him to sell groundwater. Similarly, the circumstances, under which a farmer turns out to be a buyer, are also worth investigating. In this chapter, an attempt is made to examine the determinants of groundwater markets more rigorously with the help of suitable econometric tools. More specifically, it tries to identify the factors that influence ownership of tubewells, the decision to sell and buy water of the sample farmers in the study area. This type of analysis helps us to explain why some farmers participate in groundwater markets and others do not. Furthermore, tubewell ownership, buying and selling water is a choice question of farmers. In such a situation, it is interesting to explain why a particular choice is made, what factors enter into the decision making process of a farmer and how much each factor affects the decision.

The rest of this chapter is organised under five sections. Section 6.1 deals with the methodology used to identify the determinants of tubewell ownership, water buying and water selling decisions of the sample farmers. Section 6.2 discusses factors affecting groundwater purchase decision of the sample farmers on the basis of estimated results of logit regression model. In section 6.3, the determinants of tubewell ownership have been identified and discussed with the help of the logit estimates for likelihood of ownership decision of the sample farmers. In section 6.4, the determinants of water selling decision of the tubewell owners have been examined. Factors pushing farmers to sell water and the relative significance of the factors have been identified and discussed with the help of the logit estimates for the likelihood of selling decision of the sample farmers. Section 6.5 finally sums up the whole discussion of the chapter.

6.1. Methodology:

The ownership of a tubewell, the decision to buy and sell water of a farmer are binary or dichotomous-response variables taking on the values “0” or “1”. Therefore, in order to identify the factors and their relative role in influencing these dichotomous response variables in probabilistic sense, the logit model based on cumulative logistic distribution function is found to be suitable (Maddala, 1983; Aldrich and Nelson, 1984; Cramer, 2003; Gujarati, 2004; Gujarati and Sangeetha, 2007; Hill et al., 2011)¹. In a number of empirical studies on water markets, the logit model has been used to identify the factors determining tubewell ownership, water selling and water buying decisions of farmers. In this context, mention can be made of Saleth (1991, 1992 and 1996) who has used the model to explain the determinants of buying decision of water. Singh and Singh (2006), Sharma and Sharma (2006) and Khair et al. (2012) in their empirical studies have applied logit regression model to identify the factors influencing both buying and selling decisions of groundwater based on household level primary data. The determinants of groundwater markets in terms of water buying and selling decisions are examined separately to capture the inherent differences in these two different kinds of decisions. Following Saleth (1996), the logit model used for the present empirical context can be formulated as follows.

The logit model postulates that P_i , the probability that i^{th} farmer owns a tubewell, sells and buys groundwater, is a function of an index variable Z_i summarising a set of explanatory variables X_{ki} . That is,

$$P_i = f(Z_i) = f(\alpha + \sum \beta_k X_{ki}) = \frac{1}{1+e^{-Z_i}} = \frac{1}{1+e^{-\alpha+\sum \beta_k X_{ki}}} \text{----- (6.1)}$$

Where,

Z_i = An underlying and unobserved index for the i^{th} farmer (when Z exceeds some threshold Z^* , the farmer is observed to be owner/seller/buyer (whatever the case may be); otherwise non-owner/non-seller/non-buyer.

X_{ki} = The k^{th} explanatory variable for the i^{th} farmer that may affect his decision to own tubewells/sell/buys groundwater.

$i=1, 2 \dots N$; where, N is the total number of sample farmers included in the study

$k= 1, 2 \dots M$; where M is the total number of explanatory variables.

α = Constant

β = Vector of coefficients

e = Base of the natural logarithm and approximately equals to 2.718.

Now in the estimation context, Z_i can be estimated as follows;

$$P_i = \frac{1}{1 + e^{-Z_i}}$$

$$P_i = \frac{1}{1 + \frac{1}{e^{Z_i}}}$$

$$P_i = \frac{e^{Z_i}}{1 + e^{Z_i}}$$

$$P_i(1 + e^{Z_i}) = e^{Z_i}$$

$$P_i + P_i e^{Z_i} = e^{Z_i}$$

$$P_i = e^{Z_i} - P_i e^{Z_i}$$

$$P_i = e^{Z_i}(1 - P_i)$$

$$\frac{P_i}{1 - P_i} = e^{Z_i} \text{ ----- (6.2)}$$

Taking logarithm of both sides,

$$\log\left(\frac{P_i}{1 - P_i}\right) = Z_i = \alpha + \sum \beta_k X_{ki} \text{ ----- (6.3)}$$

Thus, Z_i (in Equation 6.3), is a linear function of a host of explanatory variables. In fact Z_i^2 is equal to the natural logarithm of the odd ratio³, i.e. the ratio of probability that the farmer has owned a tubewell, sold and purchased groundwater to the probability that the farmer does not.

The goodness of fit test describes how well a model fits to a set of observations. The goodness of fit of a logit regression model can be evaluated with the help of either Wald Test or Likelihood Ratio Tests⁴. In addition to these, pseudo coefficient of determination (pseudo R^2)⁵ is also used. There are a variety of pseudo R^2 used for examining goodness of fit of a logit regression model. Though goodness of fit is estimated, in a binary regression model, goodness of fit is of secondary importance. What matters is the expected sign of the regression coefficients and their statistical or practical significance (Guajarati and Sangeetha, 2007). Therefore, based on observation in the field, a special attention will be given while interpreting the results. In order to

assess effect of each selected explanatory variable on the probability of tubewell ownership, water buying and water selling decisions of a farmer, the marginal effects and elasticity coefficients are estimated. Marginal effects are the partial derivatives of probabilities with respect to the vector of explanatory variables and computed at the mean of the explanatory variables. The value of the coefficient of marginal effects indicates the changes in decision of a farmer to own tubewell, buy and sell water which is caused by a one unit change in the independent variable, *ceteris paribus*. The elasticity coefficient indicates that 1 percent change in the explanatory variable will change the probability of farmers' decision to own tubewells, buy or sell water equal to the respective percentage of the elasticity coefficient (Khair et al. 2012).

6.2 Determinants of Buying Decision of Groundwater:

The buyers of groundwater are primarily the farmers who do not own tubewell but undertake cultivation by purchasing water usually from the nearest owner-cum-water sellers though a few sellers are also found to be water buyers on fragmented plots. In this section, an attempt is made to identify the factors that influence a farmer to buy groundwater.

As mentioned in the previous section, in order to identify the factors which influence water buying decision of a farmer, a binary logit model has been chosen. First, the sample farmers are categorised into two classes, viz., water buyers and non-buyers. Non-buyers include "self-users" and "self-users+sellers". Other categories of participants of water markets like "self-users+buyers" and "self-users+sellers+buyers" are excluded from the analysis to maintain mutual exclusiveness. Thus, as evident from Table 6.1, the total number of sample farmers considered for the analysis is 180.

For the farmers who resort to water purchase, the dependent variable is assigned the value "1" and for the farmers who are non-buyers the value of the dependent variable is taken to be "0". In this way the dependent variable becomes a binary variable taking the value "1" for farmers going for water purchase and "0" otherwise. Then a binary logit model has been applied to find out the factors affecting the sample farmers' decision to buy water.

Table 6.1
Typology of Sample Farmers According to their Decision to Buy Groundwater

Category of farmers	Decision to buy water		Total
	No	Yes	
Self-users	18	00	18 (10.00)
Self-users+sellers	76	00	76 (42.22)
Buyers	00	79	79 (43.89)
Owner+sellers	7	00	07 (3.89)
Total	101	79	180 (100)

Note: Figures in parentheses represent percentage of column total.

6.2.1 Factors Influencing Water Buying Decision:

The available theoretical and empirical literature reflects on a number of factors that determine the water buying decision of a farmer. However, subject to the availability of data and their relevance in the context of the present study, a number of factors have been identified so as to capture their possible influence on water buying decision of a farmer. The theoretical justification for the inclusion of these explanatory variables along with their definition and expected signs has been discussed below.

Own Farm Size:

Own farm size is an important factor which may affect decision of a farmer to purchase groundwater. This is due to the fact that own farm size and the ownership of tubewells are directly related with each other (Pant, 1992; Shah, 1993; Bhandari and Pandey, 2006, etc). In the previous chapter, it has been found that a majority of the buyers are marginal and small farmers. Because of smaller size of own agricultural land holding the farmer may not choose to own a tubewell and may opt for purchasing water when there is willing sellers in the vicinity of his own plots. The a priori assumption is that the own firm size of a farmer is inversely related to the probability of buying water. Thus, the expected sign of the coefficient of this variable is negative. The variable is denoted in short as *OFS*.

Size of Operational Holdings:

The available literature, empirical studies and findings of the present study show that buyers are usually the small and marginal farmers in terms size of their operational holdings. In most cases, some of them are also landless farmers. However, the size of their operational holding is found to be higher than the size of own farm land as most of the marginal or small or landless farmers posses land on lease from the village landlords as well as from the water sellers in order to undertake cultivation of any crop (which in the present study is summer rice for a specific season). In such a situation, though own farm size of a farmer is low, if the farmer has the possibility to lease in land, the farmer may choose to own a tubewell. The size of total operational holdings measured in hectare is important to consider as a factor that influences water purchase decision of a farmer. Thus, larger is the size of operational holdings lower may be the possibility to buy water. In other words, the size of operational holdings has a negative relation with water buying decision of a farmer. The variable is denoted in short as *TOHL*.

Percentage of Area under Summer Rice:

In corollary to the size of operational holding, the percentage of total operational holdings brought under summer rice cultivation, in the present study, is also an important factor that largely affects water purchase decision of a sample farmer. This is mainly because of the fact that a farmer might have large operational holding but he may not put all of them in to cultivation of summer rice as land may not be suitable for production of summer rice. It has been confirmed by the findings of the study that there is discrepancy between the two in majority of the sample farmers (56.01 percent). Since the growth of groundwater markets is primarily centered on the summer rice cultivation, area put to undertake summer rice cultivation may exert an influence on water purchase decision. Therefore, besides the size of operational holdings, the percentage of area under summer rice (denoted in short as *PAUB*) may also exert an influence on water purchase decision taken by a farmer. This in the context of present study is assumed that when percentage of area under summer rice increases the farmer is more inclined to own a tubewell. Thus, this variable has a negative impact on water purchase.

Fragmentation of Land Holdings:

When farmers' cultivable plots are dispersed in many plots, it is quite unlikely that with single water extracting device a farmer will be able to irrigate all his land (Singh and Singh, 2006). Besides, moving pumps around frequently may also cause early breakdown which may entail more cost (Bhandari and Pandey, 2006). Therefore, when degree of fragmentation is high and fragmented plots are smaller in size: a farmer may not own a pumpset or a farmer with pumpset may not be willing to own more than one pumpset rather he may prefer to buy water on fragmented plots (Singh and Singh 2003; Sharma and Sharma, 2006). In the present study fragmentation of land has been captured in terms of the number of fragmented plots where summer rice has been cultivated. Hence, we expect the variable (denoted in short as *FPLT* to bear a positive sign.

Subsidiary Occupation:

A farm family with stable subsidiary source of income may enjoy capacity to invest on pumpsets. However, such a farmer might have less concentration on farming and might not invest heavily in agriculture (Singh and Singh, 2006). The income from the subsidiary sources may also not be sufficient to own a tubewell. Therefore, a farmer with subsidiary source of income may or may not turn out to be an owner. Therefore, the probable effect of this variable on water buying decision is not conclusive. The significance and sign of the variable will determine whether it has positive or negative effect on water purchase. The role of this variable on the probability of buying water could be captured by constructing the dummy variable whether the farmer family has subsidiary income sources or not. Value "1" is assigned for having subsidiary source of income in the family, "0" otherwise. The variable, in short is denoted as *SSI*.

Education:

It is often found from the available literature that factors such as know-how of information regarding improved farm practices, managerial skills, etc. are important for effective farming. However, it is difficult to find appropriate variables to measure such factors. Education of the head of the farm family, who takes the major decision in farming, in the context of the present study can be treated as an important factor that may affect the decision to own tubewell and sell water from it. Education reflects

possible effect of human capital (Bhandari and Pandey, 2006) and managerial ability (Singh and Singh, 2006) and understanding to capture the chance to sell water as an economic opportunity (observation from the field which is discussed in section 5.1.2 in Chapter 5). Therefore, it may be hypothesised that probability of purchasing water is negatively related with the education of the farmer. Data on education of the head of the farm family is captured as the number of years of formal schooling completed by the farmer. The variable is denoted in short as *EDN*.

Age:

Like education it has also been found from available broad literature on water markets/agricultural economics that experience counts a lot in effective farming. The older the farmer the more he gets experiences in farming from practical point of view. This may encourage the farmer to own a tubewell to ensure adequacy in applying irrigation in undertaking summer rice cultivation which is a water intensive crop and based primarily on groundwater irrigation. Besides, an experienced farmer may also take an initiative to own a WED jointly in order to minimise its own share in initial investment required to buy a pumpset. These together may exert a negative impact on water buying. Age of the sample farmers in the present study is measured in terms of years. The expected role of this variable on the probability of buying water is negative.

Access to Institutional Credit:

As explained in chapter five, initial investment on tubewell requires a large capital outlay in buying the pumpset, equipments and installation of the boring. A financially capable and large farmer may be able to buy a WED through his own savings. But most of the poor farmers cannot afford to install a WED in particular and other agricultural inputs in general. Under these circumstances, in the present study it has been found that about 20 percent of the sample small and marginal farmers are dependent on borrowings from others, mostly from informal sources against an exorbitant rate of interest. This puts a huge financial burden upon the farmers that limit their capacity to buy a WED. On the other hand, the provision of formal credit may enable farmers to own a WED. At the same time as we know, land is the most important collateral in rural credit market. Since buyers' land holdings are smaller than those of sellers in the sample, thus, the inaccessibility of formal credit is one of the capacity constraints faced

by small and marginal farmers in owning a WED. This may compel a farmer to buy water. Thus, access to credit from formal sources is expected to affect ownership of tubewell of the farmer and is negatively related to the water buying decision of a farmer. Hence, the variable (denoted in short as *AIC*) should bear a negative sign. Here, a dummy variable has been constructed to capture the effect of farmers' access to institutional credit. The variable assumes the value "1" if the farm household has an access to institutional credit and "0" otherwise.

Distance of Buyers' Plots from the Nearest Tubewell:

Buying decision of water is also contingent upon whether there is tubewell near to farmers' plots (Pant, 1992). It has been found that farmers generally do not prefer to buy water from distant sources of tubewell which is constrained by availability of conveyance facilities. Therefore, if there remains a tubewell with excess capacity in the neighbourhood of farmer's plot, the farmer may choose to buy water. Distance of the sample buyers' plots from the nearest WED is measured in terms of meter. The a priori assumption is that nearer the source of irrigation water, greater is the possibility that a farmer decides to buy water. The expected sign of this variable (denoted in short as *DFNSI*) is negative.

Access to Extension Services:

Like education and age, farmer's better access to extension services given by the government is also expected to help them in adoption and use of better farming practices including timely and adequate application of groundwater. Farmers gaining knowledge on water requirement of the crop are likely to own a WED rather than resorting to water purchase. As discussed in section 5.3.6 in chapter five, in the questionnaire administered to collect primary data, nine questions related to farmers' interaction with government extension agency have been included. Farmers' responses to these queries were codified into scores. The total scores on these queries could vary from 0 to 9 depending on the level of the farmers' interaction with the extension agencies. A farmer's scores on these questions have been used as the measure of his access to extension service. Thus, if the scores of extension services increases, this implies that the farmer has better contact with the extension services deducing the benefits of the services. A farmer benefited by better extension services is expected to

have availed facilities under different schemes enabling the farmer to own a tubewell. Thus, the expected sign of the variable (denoted in short as *ACES*) is negative.

Caste:

A few available literatures also conclude that ownership of tubewell is skewed towards upper caste. It is expected that farmer who belong to upper caste may have better access to financial resources and thus be able to own a tubewell. However, in the field, no such division like upper caste and lower is observed. Rather caste as variable is captured in the field either as general caste or other backward caste or scheduled caste or scheduled tribe. Since presence of inequalities among the farmers by their caste cannot be ruled out, this variable (denoted in short as *CSTE*) is included in the study to identify whether there is any difference in the probability of buying water based on caste. The possible effect of this variable can be captured as a dummy assigning the value “1” if the farmer belongs to the general category, “0”, otherwise.

Personal Relationship:

Some of the buyers and sellers in water market have been found to be relatives of one another. Therefore, the role of kinship in affecting water purchase decision cannot be ruled out in the context of the present study. As found in the study, one of the reasons may be that buyers enjoy concession when they are relatives of the seller while on the other hand a seller can also expect other services over and above the payment for water. Because of its likely impact on decision to purchase water, kinship is considered as an explanatory variable. The expected sign of the coefficient of the variable (denoted in short as *PSNR*) is positive.

Tenancy:

Tenancy as a variable (denoted in short as *TNCY*) influencing water purchase decision assumes a significant position in the present study. Tenancy is intertwined with the operation of the water market as it has been found that as high as 42.27 percent of sample water sellers have leased out land to their buyers and about 31.95 percent of the sample water buyers also have leased in land from their respective water sellers. Therefore, it is assumed that when a buyer is a tenant of the water seller, he is more likely to enter into water contract with the water seller. This variable is taken as dummy

taking on the value “1” if the farmer is a tenant and “0” otherwise. The coefficient of this variable is expected to bear a positive sign.

The definition of the explanatory variables and expected signs of the coefficients of the variables are summarised in Table 6.2.

Table 6.2
Definition of the Explanatory Variables Influencing Farmers’ Decision to Buy Groundwater

Sl. No.	Variable	Definition	Expected sign of the coefficients
1	<i>OFS</i>	Own farm size (area in hectare)	-
2	<i>TOHL</i>	Total operational holding (area in hectare)	-
3	<i>PAUB</i>	Percentage of area under summer rice (in percent)	-
4	<i>ACIC</i>	Access to institutional credit (1 = Yes; 0, otherwise)	-
5	<i>SSI</i>	Subsidiary source of income in the farm household (1 = Yes; 0, otherwise)	-/+
6	<i>AGE</i>	Age of the head of the farm household (in years)	-
7	<i>EDN</i>	Education of the head of the farm household (in years)	-
8	<i>NFPT</i>	Nos. of fragmented plots	+
9	<i>CSTE</i>	Caste of the farm household (1 = general caste; 0, otherwise)	-
10	<i>DFNSI</i>	Distance from nearby source of irrigation (in metre)	-
11	<i>SCES</i>	Score of the extensions services (in number)	-
12	<i>PSNR</i>	Personal relation with buyers and sellers (1=Yes, 2=No)	+
13	<i>TNCY</i>	Tenancy among the farmers (1 = if the farmer is tenant; 0 otherwise)	-

The descriptive statistics of the selected explanatory variables are presented in Table 6.3.

Table 6.3**Descriptive Statistics of the Variables Influencing Farmers' Decision to Buy Groundwater**

Variable	Definition	Minimum	Maximum	Mean	Std. Deviation
<i>OFS</i>	Own farm size (area in hectare)	0	12.04	1.34	1.51
<i>TOHL</i>	Total operational holding (area in hectare)	0	4.95	1.29	0.97
<i>PAUB</i>	Percentage of area under summer rice (in percent)	0	100.00	71.50	30.19
<i>NFPT</i>	Nos. of fragmented plots	1	5.00	1.52	0.75
<i>DFNSI</i>	Distance from the nearest source of irrigation (in meter)	20	700.00	155.84	96.97
<i>AGE</i>	Age of the head of the farm household (in years)	22	77.00	46.86	11.63
<i>EDN</i>	Education of the head of the farm household (in years)	0	15.00	5.39	4.95
<i>SSI</i>	Subsidiary source of income in the farm household (1 = Yes; 0, otherwise)	0	1.00	0.46	0.50
<i>ACIC</i>	Access to institutional credit (1 = Yes; 0, otherwise)	0	1.00	0.28	0.45
<i>SCES</i>	Score of the extensions services (in number)	0	9.00	2.67	3.09
<i>PSNR</i>	Personal relation with buyers and sellers (1=yes, 2=No)	0	1.00	0.40	0.49
<i>CSTE</i>	Caste of the farm household (1 = General caste; 0, otherwise)	0	1.00	0.39	0.49
<i>TNCY</i>	Tenancy among the farmers (1 = if the farmer is tenant; 0 otherwise)	0	1.00	0.34	0.48

6.2.2 Functional Form of the Model:

Incorporating the explanatory variables discussed in the previous section, the functional form of the model specified in Equation 6.3 (under section 6.1) can be formulated for estimating the parameters affecting buying decision of the relevant sample farmers in the following manner.

$$\log \left(\frac{P_i}{1-P_i} \right) = z_i \text{ ----- (6.4)}$$

Where P_i = Probability of buying water.

$$Z_i = \alpha + \beta_1(OFS) + \beta_2(TOHL) + \beta_3(PAUB) + \beta_4(ACIC) + \beta_5(SSI) + \beta_6(AGE) + \beta_7(EDN) + \beta_8(NFPT) + \beta_9(CSTE) + \beta_{10}(DFNSI) + \beta_{11}(SCES) + \beta_{12}(PSNR) + \beta_{13}(TNCY) + U_i \text{ ----- (6.5)}$$

U_i is the error term.

The maximum likelihood estimates of the model, specified in Equation 6.5, have been obtained using STATA 11.0.

6.2.3 Results and Discussion:

The results from the logit model (specified in Equation 6.5 are) in terms of MLE estimates, marginal effects and elasticity coefficients are presented in Table 6.4.

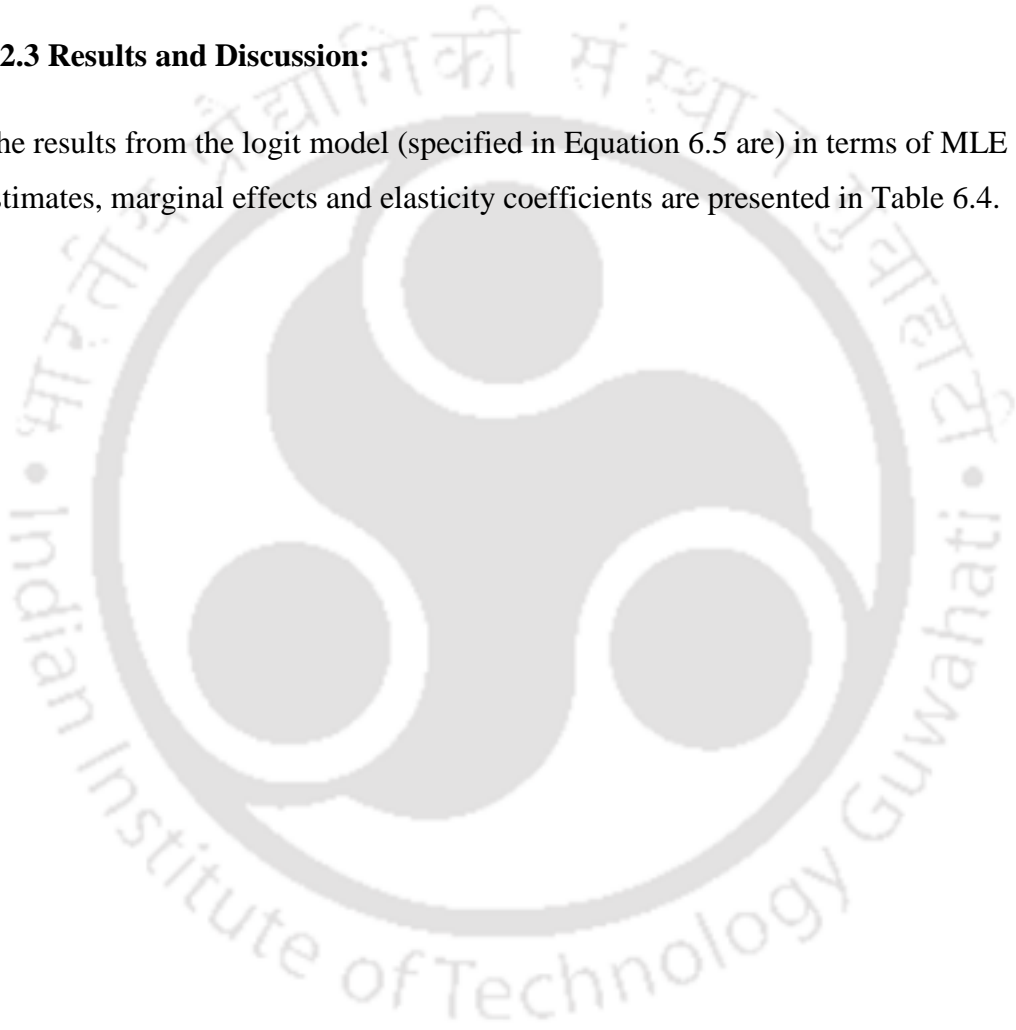


Table 6.4
Logit Estimates for the Likelihood of Water Buying Decision of the
Sample Farmers

Variables/ Particulars	MLEs		Marginal effects		Elasticity
	Coefficient	Std. Error	dy/dx	Std. Err.	ey/ex
<i>CONSTANT</i>	3.1774**	1.4285			
<i>OFS</i>	-1.1502*	0.3494	-0.2675	0.0758	-0.9717
<i>TOHL</i>	0.2946	0.3652	0.0685	0.0842	0.2408
<i>PAUB</i>	0.0090	0.0075	0.0021	0.0017	0.4046
<i>NFPT</i>	0.2447	0.2739	0.0569	0.0639	0.2353
<i>DFNSI</i>	-0.0037***	0.0023	-0.0008	0.0005	-0.3598
<i>AGE</i>	-0.0401**	0.0192	-0.0093	0.0045	-1.1867
<i>EDN</i>	-0.0757	0.0483	-0.0176	0.0112	-0.2577
<i>SSI</i>	0.4416	0.4161	0.1028	0.0969	0.1289
<i>ACIC</i>	0.1854	0.4593	0.0435	0.1090	0.0331
<i>SCES</i>	-0.1854*	0.0702	-0.0431	0.0163	-0.3132
<i>PSNR</i>	-1.7627*	0.4716	-0.3722	0.0876	-0.4419
<i>CSTE</i>	-0.2063	0.4732	-0.0476	0.1085	-0.0503
<i>TNCY</i>	0.8748***	0.5046	0.2072	0.1201	0.1893
Log-likelihood of full model:					-83.946
Log-likelihood of null model					-126.657
LR Chi ²					85.423*
Over all pseudo R ²					0.337
McFadden's Adj. R ² :					0.227
Correct prediction (in percent)					72
Crag & Uhler's R ² :					0.497
Efron's R ² :					0.396
Adj. Count R ² :					0.506
Degrees of freedom					13
Total observation					180

*, ** and *** represent significance at 1 percent, 5 percent and 10 percent levels respectively.

For a dummy variable, dy/dx is the discrete change of dummy from 0 to 1.

It is clear from Table 6.6 that the model gives a good fit as Likelihood Ratio Test (L-R Chi²) is found to be highly significant. The Variance Inflation Factor (VIF) values used

to check multi-collinearity problem, (shown in Table 6 A.1 in Annexure-6.1) have shown absence of severe multi-collinearity problem in the model. The model has provided correct prediction to the extent of 72 percent of the dependent variable. While the overall pseudo R^2 has turned out to be 0.337, the McFadden's Adjusted R^2 and Adjusted Count R^2 have been turned to be 0.227 and 0.506 respectively. Though a high value of pseudo R^{2s} is desirable, it is not always considered at par with the adjusted R^2 like in OLS. The significance of the explanatory variables, direction of change in dependent variable with respect to the explanatory variable, marginal effects and the elasticity coefficients are discussed below.

It is clear from Table 6.4 that the coefficient of "OFS" is found to be highly significant and negative, which implies that when own farm size increases the probability of buying decisions of a farmer decreases. In other words, with large own farm size farmer finds it better to own a tubewell than buying water. Thus, it is appropriate that own farm size has negative and significant influence on the decision to purchase water. The partial probability of own farm size is estimated to be (-) 0.267. This implies that other things remaining the same, one unit increase in own farm size of the farmer, will reduce the probability of water buying by 0.267 points. Similarly, the elasticity coefficient which is estimated to be (-) 0.97, implies that one percent increase in the "own farm size", leads to probability of water purchase to decrease by 97 percent, *ceteris paribus*.

Tenancy as a variable is statistically significant and its coefficient is found to be positive. This implies that if a farmer is a tenant he is more likely to be a buyer of water. Tenancy being a significant determinant of water purchase decision indicates the presence of a stronger interlinkage between the operation of water market and the land tenure system. The partial probability of tenancy is estimated to be 0.207. This implies that other things remaining the same, when a farmer becomes a tenant the probability of water buying by 0.207 points. Similarly, the elasticity coefficient which is estimated to be 0.18 implies that when the buyer turns out to be a tenant, the probability of water purchase will increase by 18 percent, *ceteris paribus*.

The coefficient of "DFNSI" is also found to be negative and significant. This indicates that when distance from the nearest source of irrigation/tubewell increases farmers' probability of buying water decreases. The partial probability of the variable is found to be (-) 0.0008 which implies that when farmer's plots from the nearest source of

irrigation increase by one meter, the likelihood of farmer's decision to buy water will decrease by 0.0008 points. The elasticity coefficient which is estimated to be (-) 0.35, implies that when distance of buyer's plots from the nearest source of tubewell increase by one percent, the probability of water purchase will decrease by 35 percent, *ceteris paribus*.

The coefficient of "AGE" is found to be negative and significant. This implies that when age of the farmer/farm household increases the probability of buying water decreases. When experience increases the farmer may find it better to own WED than buying water as water purchase is also beset with the question of reliability. The partial probability value of (-) 0.009 of the variable indicates that when age of the farmer/farm household increases by one year, the probability of farmer's decision to buy water will decrease by 0.009 points. The elasticity coefficient which is estimated to be (-) 1.18, implies that one percent increase in age of the farmer the probability of water purchase will decrease by 118 percent, *ceteris paribus*.

In the available literature (as discussed in section 5.1.8 in chapter 5) it has been found that along with market factors, the operation of the water market is also influenced by the presence of personal relationship between buyers and sellers. However, in the present study, the coefficient of "PSNR" between the buyers and sellers as a determinant of water buying decision is found to be significant but negative. This implies that the personal relationship of a farmer with the water seller does not push him to buy water. The elasticity coefficient of the variable implies that *ceteris paribus*, when a buyer has a personal relationship with the seller, the probability of water buying decision goes down by 44 percent.

The coefficient of "SCES" is found to be negative and highly significant. This indicates that when a farmer receives more extension services in the form of information on farming technology, etc. the farmer is more likely to own a tubewell rather than resorting to water purchase. The partial probability of access to extension services is found to be (-) 0.043. This implies that *ceteris paribus*, one point increase in scores of extension services will decrease the probability of water buying by 0.043 points. Similarly, the elasticity coefficient which is estimated to be 0.31 implies that one percent increase in the scores of extension services obtained by the farmer will increase the probability of water purchase by 31 percent, *ceteris paribus*.

The variable “NFT” though not significant the sign of it has been found to be positive as expected.

6.3 Determinants of Tubewell Ownership:

Since majority of the sample farmers have expressed their preference to own a tubewell to gain control over irrigation, looking at factors affecting tubewell ownership is also important. A farmer to become a water seller, first and foremost he must be owner of a tubewell. Therefore, it is important to first look at what factors enable a farmer to own a tubewell.

As mentioned above, in order to identify the factors which influence ownership of tubewell by a farmer, a binary logit model has been chosen. First, the sample farmers are categorised into two classes, viz., tubewell owner and tubewell non-owners. The total number of sample farmers included in the analysis is 198. The typology of the farmers according to their ownership of tubewell is presented in Table 6.5.

Table 6.5
Typology of Sample Farmers According to Their Decision to Own a Tubewell

Category of Farmers	Ownership of tubewell		Total
	Non-Owners	Owners	
Self-users	0	18	18 (9.09)
Self-users + sellers	0	76	76 (38.38)
Self-users+ sellers+buyers	0	14	14 (7.07)
Self-users+buyers	0	4	4 (2.02)
Buyers	79	0	79 (39.89)
Owner+sellers	0	7	7 (3.53)
Total	79	119	198 (100)

Notes: Figures in parentheses represent percentages to column total.

For the farmers who own tubewells, the dependent variable is assigned the value 1 and for the farmers who do not own a tubewell the value of the dependent variable is taken to be 0. In this way, the dependent variable becomes a binary variable taking the value

“1” for farmers owning tubewell and “0” otherwise. Then, a binary logit model has been applied to find out the factors affecting the farmers’ ownership of tubewells.

6.3.1 Factors Influencing Ownership of Tubewells:

The available theoretical and empirical literature reflects on a number of factors that determine the decision of a farmer to own a tubewell (Bhandari and Pandey, 2006). However, subject to the availability of data and their relevance in the context of the present study, the following factors have been identified so as to capture their possible influences on tubewell ownership decision of a farmer. The theoretical justification for the inclusion of these explanatory variables along with their definition has been given below.

Own Farm Size:

Given the arguments discussed in section 6.2.1, the size of own agricultural holdings (denoted in short as wfs) has been taken as an explanatory variable in the present study. Here, the a priori assumption is that the own firm size of a farmer is directly related to the probability of tubewell ownership of the farmer.

Total Operational Holdings:

Based on the arguments discussed in section 6.2, the possibility that farmers with larger size of operational holdings (denoted in short as tolh) may be associated with tubewell ownership, this is considered as an important factor that influences tubewell ownership decision of a farmer. Here, the a priori assumption is that, higher is the area of operational holding, greater is the probability that a farmer own a tubewell.

Fragmentation of Land:

Following the same logic, discussed in section 6.2.1 it can be hypothesised that when degree of fragmentation is high and fragmented plots are smaller in size: a farmer may not own pumpset set or a farmer with pumpset may not be willing to own more than one pumpset. Hence, we expect the variable to bear a negative sign.

Area under the Largest Compact Plots:

Even though a farmer might have many fragmented plots, if the dispersed plots are large in size, the farmer is more likely to own a WED. It can be hypothesized that when area under largest compact plots increases the farmer is more likely to own a WED. Therefore, area under largest compact plot (denoted in short as *AULP*) is positively related with ownership of tubewell by a farmer.

Subsidiary Occupation:

A farm family with stable subsidiary source of income may enjoy capacity to invest on pumpset. However, such a farmer might have less concentration on farming and might not invest heavily in agriculture (Singh and Singh, 2006) or the income may not be sufficient to procure a WED. Therefore, a farmer with subsidiary source of income may be able to own a tubewell. The role of this factor on the probability of owning a tubewell could be captured by the dummy variable whether the farmer family has subsidiary income sources or not. Value “1” is assigned for having subsidiary source of income in the family, “0” otherwise. The variable is denoted in short as *SSI*.

Access to Institutional Credit:

As explained in section 6.2, farmer’s access to formal credit may enable farmers to own a WED. Hence, the variable is included in the analysis and denoted in short as *aicc*. The expected sign of the variable is positive. The effect of the variable is captured as a dummy which takes the value “1” if the farm household has access to institutional credit and “0” otherwise.

Education:

Given the argument discussed in section 6.2 it may be hypothesised that the probability of owning a tubewell is positively related with the level of education of a farmer. Hence this variable is included in the analysis and denoted in short as *edn*. Information on education of the head of the farm family is recorded as the number of years of formal schooling completed by the farmer.

Age of the Farmer:

Given the argument discussed in section 6.2, experience of a farmer, which is hypothesised to be increased along with age, may encourage a farmer to own a tubewell

to ensure adequacy in applying irrigation in undertaking summer rice cultivation which is a water intensive crop. Hence, the variable is considered in the analysis. Age of the farmer is measured in terms of years. The expected role of this variable on tubewell ownership is positive.

Access to Extension Services:

Given the arguments discussed in section, 6.2, farmers' contact with the extension workers may enable a farmer to own a tubewell. Hence, the expected sign of the variable is positive.

Caste:

A few available literatures also conclude that ownership of tubewell is skewed towards higher caste. It is expected that farmer who belong to upper caste may have access to financial resources, etc. and thus be able to own a tubewell. Therefore, in the context of the present study, the variable is considered to examine how caste as a variable affects tubewell ownership. The probable impact of this variable can be captured as a dummy assigning the value "1" if the farmer belongs to the general caste, "0", otherwise.

Electricity Availability:

As noted in the previous chapter, STWs are operated with electricity or diesel. Though, in the present study, the concentration of diesel operated tubewells is more than the electricity operated tubewells, capital outlay, operation and maintenance expenditure is substantially lower in case of electric tubewells (Shah, 1993; Bhandari and Pandey, 2006; observation of the researcher). Because of low operational cost, which constitutes the major share of current expenditure in the production of summer rice among the resource poor farmers, buyers prefers to buy water from the electric tubewell than the diesel operated tubewells. Therefore, it may be hypothesised that the availability of electricity enables a farmer to own electric tubewell and attract more buyers. The role of this variable on the probability of tubewell ownership has been captured building a dummy variable (denoted in short as *AVLE*) assigning the value "1" if electricity facility is available or "0" otherwise.

The definition of the explanatory variables and expected signs of the coefficients of the variables are summarised in Table 6.6.

Table 6.6
Definition of the Explanatory Variables and their Likely Impact on Farmers' Decision to Own a Tubewell

Sl. No.	Variable	Definition	Expected sign of the coefficients
1	<i>WFS</i>	Own farm size (area in hectare)	+
2	<i>TOHL</i>	Total operational holding (area in hectare)	+
3	<i>AULC</i>	Area under the largest compact plots (in hectare)	+
4	<i>ACIC</i>	Access to institutional credit (1 = Yes; 0, otherwise)	+
5	<i>SSI</i>	Subsidiary source of income in the farm household (1 = Yes; 0, otherwise)	+
6	<i>AGE</i>	Age of the head of the farm household (in years)	+
7	<i>EDN</i>	Education of the head of the farm household (in years)	+
8	<i>NFPT</i>	Nos. of fragmented plots	-
9	<i>CSTE</i>	Caste of the farm household (1 = General caste; 0, otherwise)	+
10	<i>AVLE</i>	Availability of electricity facility (1 = Yes; 0 = No)	+
11	<i>SCES</i>	Score of the extensions services (in number)	+

The descriptive statistics of the explanatory variables considered in the model are presented in Table 6.7.

Table 6.7**Descriptive Statistics of the Explanatory Variables that Influence Farmers' Decision to Own a Tubewell**

Sl. No.	Variable		Minimum	Maximum	Mean/Mode	Std. Deviation
	Name	Definition				
1	<i>WFS</i>	Own farm size (area in hectare)	0.00	12.04	1.37	1.58
2	<i>TOHL</i>	Total operational holdings (area in hectare)	0.00	4.95	1.34	0.99
3	<i>AULC</i>	Area under the largest compact plots (in hectare)	0.13	2.01	0.80	0.45
4	<i>AGE</i>	Age of the head of the farm household (in years)	22.00	77.00	47.37	11.79
5	<i>EDN</i>	Education of the head of the farm household (in years)	0.00	15.00	5.22	4.91
6	<i>NFPT</i>	Nos. of fragmented plots	1.00	5.00	1.55	0.79
7	<i>CSTE</i>	Caste of the farm household (1 = General caste; 0, Otherwise)	0	1	0.40	0.491
8	<i>AVLE</i>	Availability of electricity facility (1 = Yes; 0 = No)	0	1	0.74	0.438
9	<i>SCES</i>	Score of the extensions services	0	9	1.67	2.017
10	<i>ACIC</i>	Access to institutional credit (1 = Yes; or 0, Otherwise)	0	1	0.24	0.430
11	<i>SSI</i>	Subsidiary source of income in the farm household (1 = Yes; 0 = No)	0	1	0.46	0.500

6.3.2 Functional Form of the Model:

Incorporating the explanatory variables discussed in section 6.3.2, the functional form of the model specified in Equation 6.3 (under section 6.1) for the estimation is specified in the following manner:

$$\log\left(\frac{P_i}{1-P_i}\right) = z_i \text{ ----- (6.6)}$$

Where, P_i = Probability to own tubewell.

$$\begin{aligned} z_i = & \alpha + \beta_1(WFS) + \beta_2(TOHL) + \beta_3(AULC) + \beta_4(ACIC) + \beta_5(SSI) \\ & + \beta_6(AGE) + \beta_7(EDN) + \beta_8(NFPT) + \beta_9(CSTE) + \\ & \beta_{10}(AVLE) + \beta_{11}(SCES) + U_i \text{ ----- (6.7)} \end{aligned}$$

U_i is the error term.

The maximum likelihood estimates of the model specified in Equation (6.7) have been obtained using STATA 11.0.

6.3.3 Results and Discussion:

The maximum likelihood estimates (MLEs) of the coefficients of logit regression model (specified in Equation 6.7), marginal effects and elasticities are presented in Table 6.8.



Table 6.8
Logit Estimates for the Likelihood of Tubewell Ownership Decision of the Sample Farmers

Variables/ Particulars	MLEs		Marginal Effects		Elasticity
	Coefficient	Standard Error	dy/dx	Standard Error	
<i>CONSANT</i>	-5.2814*	1.332549			
<i>OFS</i>	1.209369*	0.358655	0.228348	0.05379	0.419718
<i>TOHL</i>	0.049986	0.350906	0.009438	0.06632	0.016894
<i>AULC</i>	1.059901***	0.645966	0.200126	0.12307	0.21462
<i>ACIC</i>	1.045966**	0.47818	0.170697	0.06753	0.064063
<i>SSI</i>	-0.2173	0.381554	-0.04117	0.07265	-0.02551
<i>AGE</i>	0.045399**	0.018547	0.008572	0.00353	0.543313
<i>EDN</i>	0.125517**	0.049673	0.0237	0.00913	0.165603
<i>NFPT</i>	-0.17756***	0.223077	-0.03353	0.04226	-0.06956
<i>CSTE</i>	0.413706	0.436251	0.076431	0.07876	0.041703
<i>AVLE</i>	0.481328	0.468672	0.090882	0.08898	0.152928
<i>SCES</i>	0.13174**	0.065304	0.024875	0.01269	0.084553
Log-likelihood of full model					-92.433
Log-likelihood of null model					-133.87
LR Chi ²					81.48*
Overall pseudo R ²					0.305
McFadden's Adjusted R ²					0.216
Cragg & Uhler's R ²					0.456
Efron's R ² :					0.353
Adjusted Count R ²					0.443
Degrees of freedom					11
Nos. of observation					198

*, ** and *** represent significance at 1 percent, 5 percent and 10 percent levels.

For a dummy variable, dy/dx is the discrete change of dummy from 0 to 1.

It is clear from Table, 6.8 that the model gives a good fit indicated by the significant Likelihood Ratio Test (L-R Chi²) keeping in view the cross section data set used. The model has provided correct prediction to the extent of 77.78 percent of the dependent variable. The Variance Inflation Factor (VIF) values used to check multi-collinearity

(shown in Table 6A.2 in Appendix-6.1), have shown absence of severe multi-collinearity problem in the model. As evident from Table 6.8, the overall pseudo coefficient of determinations (pseudo R^2) has turned out to be 0.305. STATA has reported several measures of adjusted R^2 . While the Mcfadden's adjusted R^2 has been found to be 0.14 the adjusted count R^2 has been found to be 0.45. Though a high value of pseudo R^2 is desirable, in logit model they are not always considered at par with the adjusted R^2 like in OLS. Following is the discussion on the significance of the explanatory variables, direction of change in the dependent variable with respect to each explanatory variable, marginal effects and the elasticity coefficients.

As evident from Table 6.8 the coefficient of “*OFS*” is found to be significant and positive, which implies that when own farm size increases farmers' probability of tubewell ownership increases. In other words, with large own farm size a farmer decides to own a WED. Thus, it is appropriate that own farm size has a positive and significant influence on ownership of WED. The partial probability of own farm size is estimated to be 0.228. This implies that other things remaining the same, one unit increase in own farm size will increase the probability of ownership by 0.228 points. Similarly, the elasticity coefficient which is estimated to be 0.419, implies that one percent change in the own farm size, increase the probability of tubewell ownership by 41 percent, *ceteris paribus*.

The coefficient of “*AUL*” has been found to be positive and fairly significant. This indicates that the area under the largest compact plots induces a farmer to own a pumpset rather than resorting to buy water. The possible explanation for this could be the advantages enjoyed by a farmer with relatively larger plot in terms of scale of operation. The partial probability of the variable has found to be 0.200. This implies that when the area under the largest compact plots increases by one hectare, the probability of owning a tubewell increase by 0.214 points, other things remaining the same. The elasticity coefficient of the variable implies that one percent increase in the variable, the probability to own a tubewell will increase by 21 percent, *ceteris paribus*.

Initial investment on tubewells requires a large capital outlay in buying the pumpsets, equipments and installation of the boring. Though a financially capable and large farmer can invest on a tubewell, it has been found that the provision of formal credit may enable farmers to own a WED as the coefficient of the variable “*ACIC*” is found to

be significant and positive. The elasticity coefficient implies that when the farmer has an access to formal credit, the probability of owning a tubewell increases by 6 percent, other things remaining the same.

The coefficient of “*EDN*” has been found to be positive and significant. This implies that with education the farmer may see the benefits of ownership of WED in terms of cost and reliability in supplying water to the field during its requirement at different stages. The available literature on water markets also points to the positive impact of education on water ownership decision of the farmers (Bhandari and Pandey, 2006). The partial probability is estimated to be 0.023 which indicates that when education of the farmer increases by one year of formal schooling, the probability of the farmer to own a tubewell will increase by 0.023 points. The elasticity coefficient of 0.165 of the variable implies that when education of the farmer increased by one year of formal schooling, the probability of tubewell ownership increases by 16 percent.

The coefficient of “*AGE*” is also found to be significant and positive. This indicates that when a farmer becomes more and more experienced from the point of view of better farming, he is more likely to own a WED. The partial probability of the variable is found to be 0.008 which implies that, other things being equal, one year increase in age of the farmer/farm household will increase the probability of tubewell ownership by 0.008 points. The elasticity coefficient of the variable implies that when age of the farmer increases by one percent, the probability of tubewell ownership, *ceteris paribus*, will increase by 54 percent.

In order to explore the likely impact of number of fragmented plots on farmers’ decision to own a WED, the variable “*NFPT*” is considered in the study. The coefficient of the variable is found to be significant and negative. This implies that when the number of fragmented plots increases, the probability of farmers’ tubewell ownership decreases. The partial probability of the variable is found to be (-) 0.03. This implies that when the number of fragmented plots increases, the farmer’s probability to own a tubewell decrease by 0.03 points, other things remaining the same. The elasticity coefficient of the variable shows that, *ceteris paribus*, a one percent increase in number of fragmented plots will increase the probability of tubewell ownership of a farmer by 6 percent.

The coefficient of “ACES” is found to be positive and highly significant. This indicates that when a farmer receives better extension services in the form of information on farming practices, the farmer is more likely to own a tubewell. The observation in the field also confirms that farmers with better contact with agricultural extension workers are in a better position to avail different facilities given by the government under its different schemes. The partial probability of the variable which is found to be 0.024 implies that when the farmer’s scores on extension services increases by one point, *ceteris paribus*, the probability of tubewell ownership will increase by 0.024 points. The partial elasticity coefficient shows that one percent increase in farmer’s scores increases the probability of tubewell ownership by 8 percent, other things remaining the same.

Though the coefficients of “TOHL” and “SSI” are found to be statistically insignificant in the context of the present study but their signs are positive as expected. Similarly, the “AVLE” is not a significant determinant of ownership of tubewell. But the variable bears a positive sign as expected. In addition, “CSTE” is also not a significant determinant of ownership of tubewell by a farmer.

6.4 Determinants of Selling Decision of Groundwater:

As discussed above, in order to identify the factors which influence water selling decision of owners of tubewells, a binary logit model has been chosen. In order to construct the model, first, the sample farmers are categorised into two classes, viz., water sellers and non-sellers. Non-sellers include “self-users” and “self-users+buyers”. Other categories of participants of water markets like “self-users+buyers” and “self-users+sellers+buyers” are excluded from the analysis to maintain mutual exclusiveness. The farmers, who resort to buying groundwater without having their own tubewell, are also not included in the analysis as for selling groundwater the farmer must own a WED. As evident from Table 6.9, the total number of samples included in the analysis is 119.

For the farmers who sell water, the dependent variable is assigned the value “1” and for the farmers who are non-sellers, the value of the dependent variable is taken to be “0”. In this way the dependent variable becomes a binary variable. Then, a binary logit

model has been applied to identify the factors affecting the farmers' decision to sell water.

Table 6.9
Typology of Sample Farmers According to their Decision to Sell Groundwater

Types of Farmers	Decision to sell water		Total
	No	Yes	
Self-users	18	0	18 (15.22)
Self-users+sellers	0	76	76 (63.86)
Self-users+sellers+buyers	0	14	14 (11.76)
Self-users+buyers	4	0	4 (3.36)
Owner+sellers	0	7	7 (5.88)
Total	22	97	119 (100)

Notes: Figures in parentheses represent percentages to column total.

6.4.1 Factors Influencing Water Selling Decision:

The available theoretical and empirical literature reflects on a number of factors that determine the water selling decision of farmers (Shah, 1993; Singh and Singh, 2006; Sharma and Sharma, 2006; Khair et al., 2012). However, subject to the availability of data and its relevance in the context of the present study, the following factors have been selected as explanatory variables to capture their possible influences on water selling decision. A brief description of the variables considered in the analysis, theoretical justification for the inclusion and their expected signs are discussed below.

Own Farm Size:

Own farm size is an important factor which largely affects ownership of tubewells of a farmer. A farmer with larger own farm size may install WED with an intention to sell water. Thus, the farm size and the ownership of irrigation system is directly related and its impact on water selling is likely to be positive. However, the farmer with own WED may not be able to sell water if he has no excess capacity. Further, though he has excess capacity if there are no willing buyers in the neighbourhood, he may not be able to sell

water. Therefore, the effect of this variable cannot be anticipated a priori. The variable is denoted in short as *WFS*.

Total Operational Holding:

The available literature, empirical studies and observation of the present study show that own farm size may be small but the size of operational holdings may be high as most of the farmers have land on lease. Therefore, with larger operational holding the farmer may prefer to own a tubewell. But with larger size of operational holdings, the farmer may not be able to sell water. Because of the possibility that farmers with larger size of operational holdings is negatively related with the probability of water selling, this variable (denoted as *TOHL* in short) is considered as an important factor that influences water selling decision of a farmer. Thus, higher is the area of operational holding; lower is the probability that a farmer sell water.

Percentage of Area under Summer Rice:

Though a farmer possesses larger operational holding but he may not put all his available land under production of summer rice where actually the groundwater is used. Therefore, to understand how actual area under the cultivation of summer rice, in the present study, is linked with the probability of water selling this variable seems important. Further, since total operational holding greatly differs from the total area under summer paddy for a majority of farmers if we consider only total operational holding, we will fail to capture its actual effect. Therefore, the percentage of area under summer rice cultivation, denoted in short as *PAUB*, is considered in model. The expected influence of this factor on the likelihood of water selling is negative.

Fragmentation of Land Holdings:

Given the description of the variable (denoted in short as *NFPT*) in section 6.2, the literature of water markets point out that when degree of fragmentation is high and fragmented plots are smaller in size: a farmer may not own pumpset set or a farmer with pumpset may not be willing to own more than one pumpset. Under this circumstance the farmer may not be water seller with larger number of fragmented plots. Hence, we expect the variable to bear a negative sign.

Excess Capacity of the Tubewell:

Excess capacity of the WEDs is a significant factor influencing water selling decision of a farmer. In fact, this is one of the four conditions pointed out by Pant (1992) that has to be fulfilled for the operation of market for groundwater. Excess capacity of a WED, in the present study, is obtained by taking the difference between total capacity of the WED in terms of area that a pumpset can irrigate and the capacity utilised for own use by the owner. Based on the literature it can be hypothesised that with greater excess capacity a farmer will be able to sell water to the needy farmers. The expected sign of the variable is positive. The variable is denoted in short as “*EXC*”.

Education:

Given the description of the variable, discussed in section 6.2, education of the farmer has been considered as an explanatory variable in the model. It is hypothesised that the probability of farmer’s decision to sell water is positively related with the education of the farmer.

Age:

Considering the important role of age of a farmer in effective farming as discussed in section, 6.2, age of the farmer is included in the model as one of the important regressors. The expected sign of the variable is positive on farmer’s decision to sell water.

Caste:

Considering the fact that water transaction is also governed by social processes, the role of caste in tubewell owner’s decision to sell water has been highly recognized in the literature of water market. The variable is captured in the similar line as discussed in section, 6.2. The role of the variable on a farmer’s decision to sell water can be hypothesised in favour of general castes.

Types of WED:

It has been found that there is a general tendency among sample farmers to prefer electric tubewells as they entail lower capital outlay, operational and maintenance costs

compared to diesel operated tubewells. However, in the circumstances where presence of electricity tubewell is less or where supply of electricity is inadequate and irregular, farmers are found to be opting for diesel operated tubewells. Therefore, it has become quite important to see which type of WED in the study area has more influence on the possibility of selling decision of a farmer. Hence, this variable is incorporated in the model to find its' impact on water buying decision. However, because of the confusion discussed above the expected sign of the variable could not be ascertained. The role of this variable on the probability of selling groundwater has been captured taking two dummy variables: diesel operated WED (denoted in short as *wedd*) and electricity operated WED (denoted in short as *wede*). For the dummy variable "*WEDD*" value "1" is assigned for diesel operated WEDs and "0" otherwise for the electricity operated WED and both diesel operated WEDs and electricity operated WEDs. Similarly, for the dummy "*WEDE*" value "1" is assigned for the electricity operated WEDs and "0" otherwise for the diesel operated WEDs and both diesel run WEDs and electricity operated WEDs.

Depth of Boring:

In the present study, it has been found that there is relative scarcity of groundwater especially during the peak season of crop growth (due to simultaneous draft by the owners of WEDs). Due to this relative scarcity, a few farmers owning a WED and selling groundwater have also been found to be replacing the borings and increasing the depth of the boring. It has been found that apart from meeting own need the depth of the boring is increased to meet demand arising from willing buyers in the neighbourhood of sellers' crop field. Therefore, it is expected that an owner of tubewell with deeper boring is relatively more capable of selling water. The expected sign of this variable (denoted in short as *DTHB*) is positive on the likelihood of selling water.

Diameter of the Delivery Pipe:

It has been found that more the outlet of tubewell delivery pipe, the greater will be the water discharge and greater is the possibility that a farmer sells water (Khair et al., 2012). Therefore, diameter of the delivery pipe is taken into consideration as an explanatory variable. The expected role of this variable (denoted in short as *DMDP*) is positive on the likelihood of water selling.

The definition of the explanatory variables and expected signs of the coefficients of the variables are summarised in Table 6.10.

Table 6.10
Definition of the Explanatory Variables and their Likely Impact on Farmer's Decision to Sell Groundwater

Sl. No.	Variable	Definition	Expected sign of the coefficients
1	<i>OFS</i>	Own farm size (in hectare)	-
2	<i>TOHL</i>	Total operational holdings (in hectare)	-
3	<i>PAUB</i>	Percentage of area under summer rice to the total operational holdings (in percent)	-
4	<i>WEDE</i>	Whether electricity operated pumpset? (1 = Yes, 0 Otherwise)	+/-
5	<i>WEDD</i>	Whether diesel operated pumpset? (1 = Yes, 0 Otherwise)	+/-
6	<i>CNVF</i>	Presence of conveyance facilities (1 = Yes, 0= No)	+
7	<i>EDN</i>	Education measured by years of formal schooling last attended by the farmer (in years)	+
8	<i>EXC</i>	Excess capacity of the WEDs (in hectares)	+
9	<i>DTHB</i>	Depth of the boring (in meter)	+
10	<i>DMDP</i>	Diameter of the water delivery pipe (in centimeter)	+
11	<i>CSTE</i>	Caste (1 = General caste; 0 otherwise)	+
12	<i>AGE</i>	Age (in years)	+

The summary statistics of the explanatory variables that may be influencing a farmer's decision to sell groundwater are presented in Table 6.11.

Table 6.11
Descriptive Statistics of the Explanatory Variables that Influence Farmers’
Decision to Sell Groundwater

Variable	Definition of the variables	Min	Max	Mean	Std. Dev.
<i>OFS</i>	Own farm size (in hectare)	0	12.04	1.87	1.85
<i>TOHL</i>	Total operational holding (in hectare)	0	4.95	1.65	1.12
<i>PAUB</i>	Percentage of area under summer rice to the total operational holdings (in percent)	0	100	68.55	31.64
<i>WEDE</i>	Whether electricity operated pumpset? (1 = Yes, 0 otherwise)	0	1	0.22	0.41
<i>WEDD</i>	Whether diesel operated pumpset? (1 = Yes, 0 otherwise)	0	1	0.93	0.25
<i>CNVF</i>	Presence of conveyance facilities (1 = Yes, 0= No)	0	1	0.16	0.37
<i>EDN</i>	Education of the head of the household (class last attended)	0	15	5.60	5.11
<i>EXC</i>	Excess capacity of the WEDs (in hectare)	0	72	16.83	13.54
<i>DTHB</i>	Depth of the boring (in meter)	5.47	42.56	20.73	7.57
<i>DMDP</i>	Diameter of the water delivery pipe (in centimeter)	7.62	12.70	9.99	12.70
<i>CSTE</i>	Caste (1 = General caste; 0 otherwise)	0	1	0.41	0.49
<i>AGE</i>	Age (in years)	25	77	49.46	12.09

6.4.2 Functional Form of the Model:

Incorporating the explanatory variables discussed in the preceding section, the functional form of the model formulated in Equation 6.3, can be specified as follows:

$$\log\left(\frac{P_i}{1-P_i}\right) = z_i \text{ ----- (6.8)}$$

Where, P_i = Probability to sell water.

$$\begin{aligned} z_i = & \alpha + \beta_1(OFS) + \beta_2(TOHL) + \beta_3(PAUB) + \beta_4(WEDE) + \\ & \beta_5(WEDD) + \beta_6(CNVF) + \beta_7(EDN) + \beta_8(EXC) + \beta_9(DTHB) + \\ & \beta_{10}(DMDP) + \beta_{11}(CSTE) + \beta_{12}AGE + U_i \text{ ----- (6.9)} \end{aligned}$$

U_i is the error term.

The maximum likelihood estimates of the model defined in Equation in 6.9 have been obtained using STATA-11.0.

6.4.3 Results and Discussion:

Maximum likelihood estimates (MLEs) of the coefficients of logit regression model (specified in Equation 6.9), marginal effects and elasticities are presented in Table 6.12.

Table 6.12
Logit Estimates for the Likelihood of Sample Farmers' Decision to Sell Groundwater

Variables/Particulars	MLEs		Marginal effects		Elasticity
	Coefficient.	Standard Error	dy/dx	Standard Error	ey/ex
<i>CONS</i>	-10.2038**	4.518154			
<i>OFS</i>	-0.039105	0.306585	-0.0019	0.0151	-0.00374
<i>TOHL</i>	-0.516071	0.47757	-0.02506	0.02553	-0.0435
<i>PAUB</i>	-0.000434	0.013001	-2.1E-05	0.00063	-0.00152
<i>WEDE</i>	-1.796697***	1.075218	-0.14492	0.13794	-0.02009
<i>WEDD</i>	4.980895*	1.890212	0.811743	0.20267	0.237732
<i>CNVF</i>	2.509746***	1.398858	0.068008	0.03851	0.020504
<i>EDN</i>	0.1207763	0.08402	0.005864	0.00436	0.034587
<i>EXC</i>	0.1970809*	0.072505	0.009568	0.00337	0.169739
<i>DTHB</i>	0.0307422**	0.015069	0.001493	0.00088	0.107271
<i>DMDP</i>	0.7224127	0.495477	0.035073	0.02706	0.145406
<i>CSTE</i>	-1.264773***	0.749417	-0.07087	0.05943	-0.02665
<i>AGE</i>	0.0204639	0.028734	0.000994	0.00137	0.051792
Log-likelihood of full model					-56.96
Log-likelihood of null model					-35.62
LR Chi ²					42.69*
Overall pseudo R ²					0.3774
McFadden's Adjusted R ²					0.146
Cragg & Uhler's R ²					0.489
Efron's R ² :					0.433
Adjusted Count R ²					0.455
Correct prediction					89.92
Degrees of freedom					12
Nos. of observation					119

*, ** and *** significance at 1 percent, 5 percent and 10 percent levels.

For a dummy variable, dy/dx is the discrete change of dummy from 0 to 1.

It is clear from the Table 6.12 that the model fits very well to the data as indicated by large observed significance of Likelihood Ratio Test (L-R Chi²) which is significant at one percent level. The model has provided correct prediction to the extent of 89.92 percent of the dependent variable. The Variance Inflation Factors (VIF) values used to check multi-collinearity (shown in Table 6A.3 in Appendix 6.1), have shown absence of severe multi-collinearity problem in the model. The overall pseudo coefficient of determinations (pseudo R²) has turned out to be 0.37. STATA has reported several measures of adjusted R². While the Mcfadden's adjusted R² has been found to be 0.14 the adjusted count R² has been found to be 0.45. The significance of the explanatory variables, direction of change in the dependent variable with respect to change in the explanatory variable, marginal effects and the elasticity coefficients are discussed below.

It is clear from Table 6.12 that the coefficient of "EXC" is found to be significant and positive. This implies that when an owner enjoys excess capacity of his tubewell the probability of selling water increases. The partial probability of excess capacity is estimated to be 0.00956. This implies that other things remaining the same, one unit increase in excess capacity will increase the probability of water selling by 0.00956 points. The elasticity coefficient of the variable which is found to be 0.169 shows that one percent increase in the excess capacity (measured in hectare) enhances the probability of water selling by the owner by 16 percent, other things remaining the same.

The depth of boring has an important impact on enhancing excess capacity of the WED possessed by an owner enabling his to sell water. In the present study, the coefficient of the variable "DTHB" is found to be significant and positive. It implies that deeper boring increases the probability of water selling of farmer. The partial probability of the coefficient is found to be 0.008 which implies that, *ceteris paribus*, when depth of boring increases by one meter, the probability of water selling of the farmer, increases by 0.008 points. The elasticity coefficient of the variable shows that one percent increase in the depth of the boring will result, *ceteris paribus*, the probability of selling to increase by 10 percent. It should also be noted here that, increased depth of boring will increase cost of pumping which may discourage some of the buyers from water buying if the buyers find it too high to bear the cost.

The coefficient of the variable “WEDD” has been found to be positive and highly significant. This indicates that owner of diesel operated WED is more likely to sell water than the owner of electricity operated WED and owner of both diesel operated tubewell and electricity operated tubewell. This is also confirmed by the negative and significant coefficient of the “electricity operated WED” An insight from the field confirms that owner of electric WED likes to purchase low capacity motor specifically for own use, (2) in case of electric WED distance from the nearest WED is relatively less implying presence of more WEDs in the vicinity of the crop field exerting lower possibility of presence of willing buying and (3) in most of the cases buyers have also been found showing reluctance to buy water from electric WED as they are less reliable owing to low and irregular power supply. Therefore, it is an obvious outcome that owner of diesel operated WED finds more buyers of water.

As discussed above in section 5.1, the possibility of water transaction is conditional upon four conditions laid by Pant (1992). However the condition that there must be willing buyers in the neighbourhood of the WED can be disputed in the light of finding of the present study. It is found in the study that the coefficient of the variable presence of conveyance facilities (the most preferred facility is the plastic pipe) is significant and bears a positive sign. This indicates that the presence of conveyance facilities increases the probability of water selling when buyers’ plots lie at a technically feasible distant. The partial probability of the coefficient is found to be 0.068 which implies that presence of conveyance facility, *ceteris paribus*, will increase the probability of water selling by 0.068 points. The elasticity coefficient of the variable implies that presence of conveyance facilities, *ceteris paribus*, increases probability of water selling of the owner by 2 percent.

Caste as a variable is significant in the context of the present study. The coefficient of the variable (*CSTE*) is negative implying that, unlike findings of most of the study on water market, the probability of water selling of an owner of WED is not skewed towards general category. In fact, owners belonging to other categories have a higher probability of selling water than general caste farmers.

Education and age as variables though found insignificant in the present study, their coefficients bear a positive sign as expected.

6.5 Summing Up:

The results of the logit analysis of the determinants of tubewell ownership have shown that tubewell ownership is skewed towards the larger farm holdings. Own farm size, land fragmentation, education and age of the head of the household, access to credit and availability of off-farm income sources have been found to be significant determinants of tubewell ownership. In conformity with these determinants of tubewell ownership, own farm size, distance of buyers' plots from the nearest source of irrigation, education and age of the farmer have been found to be exerting significant impact on water purchase decision. While tenancy has been found to be a significant factor influencing a farmer's decision to be buyers of water, presence of personal relationships of farmers with the water sellers has not been found to be influencing water purchase decision of the farmer. The results of the logit analysis has shown that excess capacity of the pumpset, availability of diesel operated pumpsets and depth of the boring are some of the important factors which influence probability of groundwater selling decision of a farmer.

Thus, discussion of the chapter has helped us to indentify the determinants of groundwater market in the study area. Taking into account residual nature of the market, the market will be significant for the buyers if they find the market reliable in terms of supply of an adequate quantity of water at the time of buyer's requirement. Similarly, the sellers should also have available supply of water to meet buyer's need during peak demand periods. This requires an investigation into the issue of reliability of groundwater market in the study area. The issue of reliability of the market and the factor affecting reliability are examined in the next chapter.

Notes:

1. Ordinary Least Squares (OLS) for such specification sounds inappropriate for the following reasons:
 - OLS produces probabilities which may or may not lie between zero or one, which by definition of probability must lie between zero and one.
 - When one or more of the predictor variables are quantitative variables, the relation between values of the quantitative variable and the probability of the of the outcome

variable may not be linear. The non-linearity of relationship violates one of the basic assumptions of linear regression.

- When underlying function has a sigmoid form and the dependent variable takes only two values (0 and 1), the magnitude of prediction error are generally are not uniform across values of numbers of predictor variables. This violates the assumption of homoscedasticity of error variance that is required of OLS.

Logit is preferred over probit as there is little theoretical justification for choosing between probit and logit models as they often produce similar results (Aldrich and Nelson, 1983; Green, 2003; Stock and Watson, 2003). Gujarati and Sangeetha (2007) notes that researchers generally prefer logit model because of comparative mathematical simplicity.

2. Z_i the natural logarithm of the odd ratio is referred to as logit. It is also called logit transformation as it transform Y which is restricted in the range of [0,1] to a range of $[-\infty, +\infty]$.

3. A odds ratio is the ratio of odds of success for one group divided by odds of success for another group

4. Log of the likelihood (-2LL) estimated, defined in the following manner, has been used. A higher value of the LL implies a poorer model fit.

$$LL = \sum (y_i * \ln \hat{P}_i) + (1 - y_i) * \ln (1 - \hat{P}_i)$$

Taking the natural log of \hat{P}_i values, $\ln \hat{P}_i$ always results in a negative value, because the value of \hat{P}_i must be less than 1 and the natural log of value below 1 are all negatives numbers. Thus, LL is sum of negative values and is always negative. LL tends to be close to be zero when actual group membership are close to the predicted probabilities for the most cases; as predicted probabilities get further away from actual group membership the negative values of LL become larger in absolute value. To test whether the model fitted perfectly, LL is multiplied with -2 to obtain chi-square test. In this test the large observed significance level indicate that the model do not differ significantly from the perfect model. Chi-square test is obtained as follows:

$$\chi^2 = -2(LL_{null\ model} - LL_{full\ model})$$

5. There are various measures of pseudo R^2 reported by different software for statistical analysis. Like Cox and Snell's R^2 (its maximum value is always less than one) and Nagkerke's R^2 (obtained by dividing the obtained Cox and Snell R^2 given the marginal distribution of scores on the predicted and outcome variable. It can take a maximum value of 1) are reported by SPSS and McFadden adjusted R^2 , Cragg & Uhler's R^2 , Efron's R^2 and Adjusted Count R^2 reported by STATA.

Appendix – 6.1

Collinearity Diagnostics for Independent Variables Influencing Tubewell Ownership, Buying and Selling Decisions of a Farmer

Table A6.1: Collinearity Diagnostics for independent variables influencing water buying decision of a farmer

Variable	VIF	SRT VIF	Tolerance	R-Squared
<i>OFS</i>	1.71	1.31	0.58	0.42
<i>TOHL</i>	1.49	1.22	0.67	0.33
<i>PAUB</i>	1.28	1.13	0.78	0.22
<i>NFPT</i>	1.04	1.02	0.97	0.03
<i>DFNSI</i>	1.16	1.08	0.86	0.14
<i>AGE</i>	1.28	1.13	0.78	0.22
<i>EDN</i>	1.41	1.19	0.71	0.29
<i>SSI</i>	1.14	1.07	0.87	0.13
<i>ACIC</i>	1.13	1.06	0.89	0.11
<i>SCES</i>	1.17	1.08	0.85	0.15
<i>PSNR</i>	1.40	1.19	0.71	0.29
<i>CSTE</i>	1.35	1.16	0.74	0.26
<i>TNCY</i>	1.25	1.12	0.80	0.20
Mean VIF	1.29			

Table A6.2: Collinearity Diagnostics for independent variables influencing tubewell ownership decision

Variable	VIF	SRT VIF	Tolerance	R-Squared
<i>WFS</i>	1.74	1.32	0.57	0.43
<i>TOHL</i>	1.69	1.30	0.59	0.41
<i>AULC</i>	1.63	1.28	0.61	0.39
<i>ACIC</i>	1.06	1.03	0.94	0.06
<i>SSI</i>	1.14	1.07	0.87	0.13
<i>AGE</i>	1.27	1.13	0.79	0.21
<i>EDN</i>	1.39	1.18	0.72	0.28
<i>NFPT</i>	1.04	1.02	0.96	0.04
<i>PAUB</i>	1.27	1.13	0.78	0.22
<i>CSTE</i>	1.44	1.20	0.70	0.31
<i>AVLE</i>	1.28	1.13	0.78	0.22
<i>SCES</i>	1.19	1.09	0.84	0.16
Mean VIF	1.34			

Appendix – 6.1

Table A6.3: Collinearity Diagnostics for independent variables that affect water selling decision

Variable	VIF	SRT VIF	Tolerance	R-Squared
<i>OFS</i>	1.55	1.24	0.65	0.35
<i>TOHL</i>	1.42	1.19	0.71	0.29
<i>PAUB</i>	1.43	1.20	0.70	0.30
<i>WEDE</i>	1.78	1.33	0.56	0.44
<i>WEDD</i>	1.42	1.19	0.70	0.30
<i>CNVF</i>	1.20	1.10	0.83	0.17
<i>EDN</i>	1.53	1.24	0.65	0.35
<i>EXC</i>	1.43	1.20	0.70	0.30
<i>DTHB</i>	1.44	1.20	0.69	0.31
<i>DMDP</i>	1.06	1.03	0.94	0.06
<i>CSTE</i>	1.31	1.14	0.77	0.23
<i>AGE</i>	1.26	1.12	0.79	0.21
Mean VIF	1.40			

Notes: There are many recommendations for acceptable levels of VIF. While the most commonly suggested maximum level of VIF is 10 (Kennedy, 1992), a recommended maximum VIF value of 5 and even 4 have also been found in the literature. Considering the most commonly used VIF value of 10, the presence of collinearity in preferred model has been checked.

CHAPTER SEVEN

RELIABILITY OF GROUNDWATER MARKETS AND ITS DETERMINANTS

In the previous chapter, the determinants of groundwater market have been identified with the help of a logit regression analysis. More specifically, the factors that influence ownership of tubewells and decisions to buy and sell groundwater of the sample farmers have been examined. On the whole, it has been found that farm size, availability of conveyance facility, excess capacity of the pumpsets, access to institutional credit, interlinkage of the market with land tenure system are some of the significant factors which affect a farmer's decision to buy and sell water. However, groundwater markets continue to be significant for the buyers as long as the market is reliable for them. A buyer finds the market reliable when the supply of adequate amount of water, when needed, is not affected. The question of reliability of groundwater markets is worth investigating because adequate water supply ensured by a reliable groundwater market enhances the output of the crop undertaken for cultivation (Banerji et al., 2006). It is evident from the discussion on the structure and functioning of the market in chapter five that the market is to some extent exploitative and water transaction is affected by the social processes. The non-market dimensions of the market such as, personal relationship between buyers and sellers, influence of tenancy on water contract, farmers' preference for electricity operated tubewells, relative scarcity of groundwater in a few sample locations, etc. may affect reliability of the market. Therefore, an attempt has been made in this chapter to examine the issue of reliability and to explore the factors ensuring reliability of water market.

The rest of the chapter is organised under six sections. Section 7.1 deals with the theoretical issue of reliability of groundwater markets. Section 7.2 discusses the issues of reliability of groundwater markets in the study area. Section 7.3 discusses the factors that may contribute to reliability of groundwater markets with insights from literature of water market and field survey. Section 7.4 focuses on the specification of the econometric model used to examine the determinants of reliability of groundwater markets. In section 7.5, logit estimates of the likelihood of selected factors ensuring

reliability of the market has been discussed in detail. Section 7.6 finally sums up the whole discussion of the chapter.

7.1 Reliability of Groundwater Markets:

A major advantage of private ownership of tubewell based irrigation technology is its flexibility in delivering water to the field as and when required. An owner enjoys this as long as water is available and there is no machine breakdown or in cases like pumpset failure if there is fast repairment or replacement (Meinzen-Dick, 1998). However, usually this is not the case with the water buyers. For the fulfillment of demand for water of the buyers during the entire crop growth period, there is always a question of adequate supply. It is mainly due to the basic feature of the market (around which the market has evolved) that water is normally sold to willing farmers after meeting own irrigation requirement of owners of WEDs (Shah, 1993; Pant, 1992; Singh and Singh, 2003; Zhang, 2006; Dutta, 2012, etc.). In this sense, the groundwater market is largely of the nature of a residual market failing to meet water demands of the buyers during the period of high demand (Bhandari and Pandey, 2006). Thus, the non-availability of groundwater to the owner-cum-sellers for their own use as well as for sale and inadequate supply faced by the water buyers when needed, indicate non-reliability of groundwater markets in fulfilling farmers' needs for irrigation. In the literature on water market this aspect of the market is discussed as the issue of reliability of groundwater markets (Shah, 1993; Meinzen-Dick, 1998; Singh and Singh, 2002; Hussain et al., 2005; Banerji et al., 2006; Dutta, 2012, etc.). Thus, the aspects of reliability of groundwater markets are both supply-side and demand-side.

The indicators of reliability of groundwater markets have two aspects: (1) from the water sellers' point of view, whether the sellers have sufficient supply of water to meet the buyers' needs when requested, usually after meeting their own requirement; and (2) from the buyers' point of view, whether water is always available when requested or needed by the buyers (Meinzen-Dick, 1998). Taking a cue from this, an attempt has been made to get a better insight into the reliability of groundwater markets in the study area. In this regard, both sample sellers and buyers were asked whether water was always available when needed.

7.2 Reliability of Groundwater Markets in the Study Area:

As mentioned in the previous section, an attempt was made in the study to elicit information on the question of reliability of groundwater markets from the sellers as well as the buyers. When sample water sellers were asked whether groundwater was always available when needed for both own use and selling, almost all of them reported that water had been largely available. However, out of the total 97 sample sellers, about 49.48 percent have reported that they have found water to be less available to meet their requirement for both own use and sale. The distribution of sample sellers according to the reasons attributed by them for non-availability of groundwater has been presented in Table 7.1.

Table 7.1
Distribution of Sample Sellers According to the Reasons for Non-availability of Water

Reasons	Number of sample sellers
Pumpset failure (mechanical breakdown as some pumpsets are old)	15 (31.25)
Boring failure	04 (08.33)
Pumpset failure + boring failure	08 (16.67)
Relative scarcity when pumpsets are operated concurrently	21 (43.75)
Total	48 (100.00)

Notes: Figures in parentheses represent percentage to column total.

It is clear from Table 7.1 that among the sample sellers who have faced non-availability of groundwater, about 43.75 percent have faced relative scarcity of water during peak water demands owing mainly to simultaneous drafting by the owner of pumpsets. They have, however, reported that it has not largely affected their capacity to sell water. In instances where owners of pumpsets face relative scarcity, they have been found to be making adjustment by not running all the pumpsets simultaneously. The remaining 56.27 percent have attributed the reasons for non-availability of groundwater to pumpset failure and boring failure. However, almost all owners of electricity operated tubewells have reported that they have faced non-availability of groundwater for own use and for sale owing to electricity shortages. They are also of the opinion that electricity supply is largely insufficient and irregular during the farming season. Thus, in the study area, groundwater has been found to be not available for the water sellers during the peak demand periods mainly due to relative scarcity of groundwater arising

from simultaneous drafting in a few locations, during mechanical breakdown and during the periods of electricity shortages in the case of the owners of electricity operated pumpsets. Hence, on the supply side, the availability of water to the owner-cum-sellers is conditioned by a limited number of factors like condition of the pumpsets, relative scarcity of groundwater due to simultaneous drafting by all the farmers and inadequate supply of electricity.

While looking at the issue of reliability of groundwater markets from the buyers' point of view, it has been found that as many as 60 sample buyers (around 62 percent of the total sample buyers) have reported that they have found the market unreliable in meeting their own needs. This number is found to be high compared to the findings of Meinen-Dick (1998), who in a study on reliability of water market in the Punjab province of Pakistan, found that nearly half of the sample buyers had reported the market to be unreliable. Table 7.2 shows that about 36.67 percent of the sample buyers (who have found the market unreliable) have found it unreliable as their respective sellers could not supply water due to presence of multiple buyers, their inability to buy diesel and for some other unspecified reasons. An equal number of buyers (about 36.67 percent) have been unable to buy diesel to run the pumpsets at the time of requirement. As discussed in section 5.1.6 of chapter five, the general practice in the market is such that a buyer is required to buy diesel for operating the pumpsets. While about 8.33 percent have reported frequent pumpset failure, about 1.67 percent have attributed it to an inadequate supply of electricity for running the respective sellers' pumpsets. About 16.67 percent have not cited any specific reason for non-availability of water for them.

Table 7.2
Distribution of Sample Buyers According to the Reasons for Non-availability of Water

Reasons	Number of sample sellers
Frequent pumpset failure	05 (08.33)
Inability to buy diesel to run the pumpsets	22 (36.67)
Sellers failed to supply due to large number of buyers + inability of buyers to buy diesel + other reasons	22 (36.67)
Electricity shortage	01 (01.67)
Others	10 (16.67)
Total	60 (100)

Notes: Figures in the parentheses represent percentage to column total.

It is evident from Table 7.2 that additionally, some other sample buyers who have found the market unreliable could not specifically point out the reasons for non-reliability of water market. Thus, it is imperative to delve into the issue of reliability of the market in details to explore how the nature and functioning of the market is linked with it. It has also been found that there is a strong interlinkage between operations of the market and the existing land tenancy (discussed in section 5.1.7 of chapter five). On enquiry into the link between tenancy and reliability of the market, it has been found that about 29.70 percent of the sample buyers, who have reported the market to be reliable, are tenants of the water sellers. This indicates that reliability of the market may also be related to the existing land tenure system. Moreover, personal relationships between water buyers and sellers (as discussed in section 5.1.8 in chapter five) and its role in the reliability of the market also cannot be ruled out. In the present study, as high as 62.16 percent of the buyers who have found the market reliable, have personal relationship with their existing sellers. But in order to get a better insight into the issue of reliability of the market, partial influence of these factors has to be ascertained. Therefore, to examine the factors which may ensure reliability of market, the use of econometric tool is felt necessary. Further, in view of the fact that the reliability of the market for the sellers is linked with availability of water conditional upon limited factors (discussed above), we will be able to understand the link between reliability and nature of the market if we examine the same from the buyer's point of view. Meinzen-Dick (1998) on this count also notes that water buyers are in a position to identify how the nature and functioning of the market affects reliability of groundwater markets. Hence, an investigation into the circumstances under which a buyer finds the market reliable, has been examined in the following section from the buyers' point of view. More specifically, it tries to explore the determinants of reliability of the market.

7.3 Factors Influencing Reliability of Groundwater Markets:

The reliability of groundwater markets, defined in terms of its ability to supply adequate quantity of water to the buyers, depends on a variety of factors. These include farm households' asset bundles and socio-economic characteristics [(age, education of the head of the households, relationship (relative or landlord), caste, community, family size, farm size)]; characteristics of the tubewell technology used (sources of power, depth of boring, diameter of the boring, types of tubewells, capacity of the pumpset);

land ownership, forms of tenancy, forms of contract in labour and land market, pricing of water, government policy (subsidy in power supply), farm size of the seller, priority given by the owners of tubewell on own plots, etc. (Shah 1993; Meinzen-Dick, 1998; Saleth, 1997; Jacoby, 2004; Singh and Singh, 2003; Banerji et al., 2006, etc.). In a similar context, Meinzen-Dick (1998) and Hussain et al. (2005) in their studies in Pakistan found capacity of the tubewells, types of fuel/power used in tubewells and size of own landholdings of the buyers to be significant factors contributing to reliability of water market.

Thus, the available theoretical and empirical literature reflects on a number of factors which determine reliability of groundwater markets. However, subject to availability of data and their relevance in the context of the present study, a few important factors have been identified so as to capture their partial influence on reliability. The theoretical justification for the inclusion of these factors along with their description and expected influence on reliability of the groundwater market has been discussed below.

Own Farm Size:

The size of own agricultural land holding is an important factor affecting reliability of groundwater markets. It is usually due to the fact that water sellers find it difficult to refuse request for water from larger land-owners as landownership is associated with social status in a locality (Meinzen-Dick, 1998). Because of its significant impact upon reliability of purchased water, the size of the own farmland of a buyer as identified by previous empirical study, this variable (denoted in short as *OFS*) has been included as an explanatory variable in the present study. The a priori assumption is that the own farm size of a farmer is positively related to the probability of the groundwater market being reliable to a buyer.

Cultivated Area of the Buyers:

When own farm size holding is supposed to act as a specification for social status of the farmers, what may be deemed important is the size of the farm operated. When area actually put into operation increases, the buyers may not be able to buy water for the whole acres of land affecting timeliness and adequacy in application of groundwater for crop growth. Further, the sellers may also find it difficult to supply water to such

buyers with large operational holdings as sellers sell water only after meeting their own requirement. As explained in Chapter four, the farmers are found not to undertake cultivation in the whole area of their operational holdings. Therefore, if operational holdings are taken into consideration, it may not capture the actual impact. Therefore, as an approximation to evaluate the likely impact of this, the area under summer rice cultivation resorting to water purchase, is included for the specification of the model. Hence, in the context of the present study it is assumed that when the quantity of water purchase (measured in terms of area put into cultivation of summer rice based on purchased water) increases the buyers may not be able to buy water in time to fulfill their requirement resulting in the market to be less reliable. Thus, the relationship between this variable and the probability that a farmer find the market reliable is assumed to be negative. The variable in short is denoted as *ARAB*.

Sources of Power/Fuel:

As discussed in Chapter five, the STWs are operated using electricity or diesel. Although the concentration of diesel operated tubewells is more than the electricity operated tubewells in the study area, capital outlay, operation and maintenance expenditure is substantially lower in case of electric tubewell (Shah 1993; Bhandari and Pandey 2006; findings of the study discussed in section 5.2.2 of chapter five) Because of low operational cost (which constitutes the major share of current expenditure in the production of summer rice) sample buyers prefer to buy water from the electric tubewells. However, in the circumstances where the number of electricity operated tubewells is less or where supply of electricity is inadequate and irregular, the buyers are found to be opting for diesel operated tubewells. Therefore, it has become quite important to see which type of WED in the study area has greater influence on the timeliness and adequacy in the supply of purchased water. In the field, no buyer has been found to be buying water from both types of tubewells. This variable (denoted in short as *TPFUEL*) is, therefore, incorporated in the model to examine its likely impact on reliability of the groundwater market in the study area. In order to capture the likely impact of this variable, a dummy variable is constructed. The variable assumes the value “1” if the WED is diesel operated or “0” for electricity operated tubewells. Considering the observation in the field, the coefficient of the variable can be expected to bear a positive sign.

Depth of Boring:

It has been found in Chapter six that a farmer with deeper boring is relatively more capable of selling water compared to the owners of tubewells with relatively shallow boring. It is due to the fact that with deeper boring a farmer is capable of extracting more groundwater enjoying the advantage of possessing surplus water for sale. At the same time, boring failure is many a time (reported by the sample sellers) is dependent upon the depth of the boring. Therefore, a buyer buying water from a deeper boring is able to receive a more reliable supply of water than from a shallow one. Hence, it is assumed that when the depth of boring of the tubewell from which the buyers purchase groundwater increases, more reliability is ensured. Thus, the relationship between the variable and its impact on reliability of the market is assumed to be positive. The variable in short is denoted as *DPTHB*.

Mode of Payment of Water Charge:

The mode of payment of water charge also largely affects the reliability of irrigation services to a considerable extent. It has been found in the field that while buyers prefer the payment in kind, sellers generally prefer the payment in the form of cash. Since kind payment involves payment at the time of harvest, in order to reduce the risk of uncertainty in the payment of water charge in the future, sellers usually prefer payment in cash. The observation in the field suggests that the buyers who make payment in cash are expected to find the market more reliable. In order to capture the likely impact of this variable (denoted in short as *CORK*) a dummy variable is constructed. The dummy takes the value “1” if the payment takes place in cash and “0” otherwise for payment under kind or in both cash and kind. The expected sign of the coefficient of this variable is positive meaning a buyer making payment in cash finds the market more reliable.

Amount of Water Charge:

Jacoby et al. (2004) have found that when farmers care more about reliability of water supply, they are willing to pay higher prices than the others. As much variation has been found in the field in water charges among different categories of water buyers (depending on personal relationships between buyers and respective sellers), it may be hypothesised that groundwater market ensures adequate supply of water when the water

charge paid by a buyer is relatively higher than that of the others. Here, the price for water per hectare is considered. Payment made in kind is converted into equivalent monetary value by multiplying the quantity paid by the existing market price of the crop for the season. In instances, where the farmer's output has not reached the market, average of the prices realised by the other buyers is considered while calculating the monetary value of the total quantity of the produce under kind payments. The expected sign of the coefficient of this variable is also assumed to be positive. This variable in short is denoted as *PRICE*.

Forms of Non-cash Payment: Fixed Charge or Output Sharing:

Although payment of water charge made in cash may enhance the reliability of the market, looking at in-kind payment simply may not capture the whole range of effects of water contract on reliability. As outlined in section 5.1.5 of chapter five, kind payments take the forms of fixed amount of the produce or output sharing or both. In output sharing form of contract the water seller has a stake in the outcome of the crop and thus shares the risk of crop failure if the water supply does not meet crop needs (Meinzen-Dick, 1998). Thus, in the case of water traded against output sharing, the seller has an incentive to supply adequate tubewell water in a timely manner (Meinzen-Dick 1998, Aggarwal, 1996). This, in turn, makes the market more reliable for the buyers. In order to capture the probable impact of this variable two dummy variables have been constructed. The variable labeled as "*KFC*" assumes the value "1" if the form of water contract is in kind (fixed charge), "0" otherwise for in kind with output sharing and both in kind (fixed charge) and in kind (output sharing). Similarly, the variable labeled as "*KOS*" assumes the value "1" if the form of water contract is in kind (output sharing), "0" otherwise for the both. The relationship of between output sharing in kind payment and the probability of reliability of the market is assumed to be positive. However, the relationship between in kind payment (fixed) and the probability of reliability of the market is not conclusive. Therefore, it will be examined after looking at the sign and significance of the coefficients of the variables.

Subsidiary Occupation:

The prevalent practice in groundwater market in the study area shows that the buyers are required to pay for the fuel themselves if the pumpset is diesel operated. In such a

situation, the tubewell may be available but the buyer may not have sufficient money to buy diesel to operate the pumpsets. Therefore, the availability of a subsidiary source of income in the farm household may enable the buyers to purchase the required amount of fuel to extract groundwater in time. The likely relationship between the availability of subsidiary sources of income and the reliability of the market is expected to be positive. The role of this variable on the probability of reliability could be captured by constructing a dummy variable as to whether the farmer family has subsidiary income sources or not. Value “1” is assigned for having any subsidiary source of income in the farm household, and “0” otherwise. The variable is denoted in short as *SSI*.

Education:

It is often found from the available literature that those factors such as know-how on advanced farm practices, experiences and managerial skills are important for effective farming. However, it is difficult to find appropriate variables to measure the impact of such factors. Education of the head of the farm family, who takes the major decisions in farming, in the context of the study can be treated as an important factor that may affect buyers’ calculation regarding time and amount of water requirement, thereby influencing reliability of the groundwater market. The expected sign of the coefficient of this variable (denoted in short as *EDN*) is positive.

Personal Relationship:

As discussed in section 5.1.8 of chapter five, some of the buyers and sellers in groundwater markets have been found to be the relatives of one another. Therefore, the role of kinship in affecting reliability of the market cannot be ruled out in the context of the present study. As found in the study, buyers prefer the sellers who are their relatives because by doing this they can enjoy some concession at the time of payment of water charge and can expect adequate provision of groundwater in their needs. Because of its likely impact on timely and adequate supply of groundwater, kinship is taken as an explanatory variable. The likely impact of this variable is also captured by a dummy variable which assumes the value “1” when the buyers are relatives of the water sellers and “0” otherwise. The expected sign of the coefficient of the variable (denoted in short as *PSNR*) is positive on the probability that the buyers find the market reliable for them.

Caste:

Like in the case of personal relationship, literature on groundwater markets points out that sellers are found to be a little more flexible and kind towards buyers belonging to higher castes. Thus, there is differential treatment to buyers based on caste. It is expected that farmers belonging to upper castes may have access to an adequate supply of water and this, in turn, enables them to enjoy reliability of the groundwater market. Though, in the field, no such sharp distinction between upper and lower castes has been noticed, in order to identify the presence of any inter caste difference in ensuring reliability, this variable is included in the analysis. The possible effect of this variable (denoted in short as *CSTE*) has been captured as dummy assigning the value “1” if the farmer belongs to the general caste or “0” otherwise. Since, the relationship between this variable and its likely impact on reliability of the market is not conclusive the direction of the relationship will be discussed after the analysis.

Other Services:

It has been outlined in section 5.1.10 of Chapter five that apart from the payment of water charge, the buyers are also required to render some other services as and when asked by the water sellers. A buyer provides these services to maintain a cordial relationship with the water sellers so that he is not refused water at the time of requirement. Therefore, it can be expected that the reliability of the groundwater market may also get influenced by the fact whether the buyer is rendering other services to the seller or not. In order to study the impact of this practice, a dummy variable (denoted in short as *OTHS*) is constructed taking on the value “1” if the buyer renders other services to the water sellers and “0” otherwise. The coefficient of this variable is expected to bear a positive sign indicating a positive relationship between the two.

Tenancy:

Tenancy as a variable influencing reliability of groundwater market assumes importance in the context of the present study. It has been found that most of the sample buyers (around 31.95 percent) have land on lease from the respective water sellers. Thus, the groundwater market is found to be interlinked with the existing tenancy system. At the same time, as discussed in section 7.2, about 29.70 percent of the buyers who have found the market reliable are tenants of their respective water

sellers. Therefore, it is assumed that when a buyer is a tenant of the water seller, he is more likely to get an adequate amount of water at the time of requirement. This variable, denoted in short as *TNCY*, is included as a dummy variable taking the value “1” if the farmer is a tenant of the water seller and “0” otherwise. The coefficient of this variable is expected to bear a positive sign.

The definition of the explanatory variables and expected signs of the coefficients of the variables are summarised in the Table 7.3.

Table 7. 3
Definition of the explanatory Variables and their Likely Impact on Reliability of Groundwater Markets

Sl. No.	Name	Definition	Expected sign
1	<i>OFS</i>	Own farm size (area in hectare)	+
2	<i>ARAB</i>	Cultivated areas of the buyers (in hectare)	-
3	<i>TPFUEL</i>	Types of fuel/power (1=Diesel operated tubewells, “0” Otherwise)	+/-
4	<i>DPTHB</i>	Depth of the boring (in metre)	+
5	<i>SSI</i>	Subsidiary sources of income in the farm household (1 = Yes; 0 = No)	+
6	<i>EDN</i>	Education of the head of the farm household (in years of formal schooling by the farmer)	+
7	<i>CSTE</i>	Caste of the farm household (1 = General; “0”, Otherwise)	+/-
8	<i>PSNR</i>	Personal relationship with the sellers (1 = Yes; 0 = No)	+
9	<i>OTHS</i>	Other services rendered by the buyers (1 = Yes; 0 = No)	+
10	<i>TNNCY</i>	Buyers leased-in land from the seller? (1 = Yes; 0 = No)	+
11	<i>CORK</i>	Mode of payment (1 = Cash; “0”, Otherwise)	+
12	<i>PRICE</i>	Water charge (in rupees)	+
13	<i>KFC</i>	Fixed-based kind payment (1 = If kind payment is fixed-based; 0, Otherwise)	-/+
14	<i>KOS</i>	Output sharing kind payment (1 = If kind payment is output sharing; “0”, Otherwise)	+

The summary statistics of the explanatory variables selected for the analysis are presented in Table 7.4.

Table 7.4
Descriptive Statistics of the Explanatory Variables Influencing
Reliability of Groundwater Market

Sl. No.	Variables	Minimum	Maximum	Mean	Std. Deviation
1	<i>OFS</i>	0.00	8.29	0.89	1.15
2	<i>ARAB</i>	0.13	3.08	0.66	0.46
3	<i>TPFUEL</i>	0.00	1.00	0.82	0.38
4	<i>DPTHB</i>	06.00	42.00	20.47	7.25
5	<i>SSI</i>	0.00	1.00	0.45	0.50
6	<i>EDN</i>	0.00	15.00	4.49	4.61
7	<i>CSTE</i>	0.00	1.00	0.43	0.50
8	<i>PSNR</i>	0.00	1.00	0.34	0.48
9	<i>OTHS</i>	0.00	1.00	0.36	0.48
10	<i>TNCY</i>	0.00	1.00	0.32	0.47
11	<i>CORK</i>	0.00	1.00	0.23	0.42
12	<i>PRICE</i>	1120.50	11205.00	5056.90	1753.96
13	<i>KFC</i>	0.00	1.00	0.49	0.50
14	<i>KOS</i>	0.00	1.00	0.28	0.45

It is evident from Table 7.4 that the average own farm size of the sample buyers is 0.89 hectare. It is found that there are farmers who do not own cultivable land. The maximum own farm size is 8.29 hectares. The area for which the groundwater is bought ranges widely from a minimum of 0.133 hectare per farm household to 3.08 hectares. Regarding the use of fuel for running the pumpsets, it has been found that about 80 percent of the buyers use diesel while the rest use electricity. The average depth of boring is approximately 20.47 meter. However, there is a large variation in the depth of the boring ranging from a minimum of 6 meter to a maximum of 42 meter depending upon the location. The variable off-farm income in the family is a dummy variable. More than 45 percent of the total farm households are engaged in off-farm income generating activities. The average years of schooling of the sample farmers is 5 years which implies that they are primary level schooling passed. The minimum is “0” indicating they are illiterate. The maximum of 15 implies they are postgraduate. Regarding the castes of the buyers, about 43 percent belong to the general caste. While

about 33 percent of the buyers have personal relationships with their respective sellers, about 32 percent render other services to the sellers in order to maintain a cordial relationship with the seller. The majority of the buyers (approximately about 77 percent) make payment in the form of kind, out of which 28 percent of the in kind payment take the form of output sharing. The average charge for water per hectare of land area for the whole season is ₹ 5, 056.90 while the minimum and maximum charge per hectare is ₹ 1, 120.50 and ₹ 1, 1205.00 respectively.

7.4 Specification of the Model:

In the instances where the dependent variable is a binary variable taking on the value “1” or “0”, a logit or probit regression model is most commonly used to analyse factors affecting the dependent variable. However, the binary logit model is a popular statistical technique in which the probability of a binary or dichotomous outcome is related to a set of explanatory variables and has been widely applied in such studies (Meinzen-Dick, 1998). As reliability of groundwater markets is a binary or dichotomous-response variable (reliable or unreliable) taking on the values “1” or “0”, and we are interested in understanding the relative role of the factors that may affect this in a probabilistic sense, the logit model based on cumulative logistic distribution function is found to be suitable (Maddala, 1983; Gujarati, 2004; Gujarati and Sangeetha, 2007; Hill et al., 2011). In order to construct the model, farmers are first categorised into two classes on the basis of their responses to the question of reliability. The two classes are farmers who have found the market reliable and those who found the market unreliable. For the sample farmers who have found the market reliable, the dependent variable is assigned with the value “1” and for the farmers who have not found the market reliable the value of the dependent variable is taken to be “0”. In this way the dependent variable becomes a binary variable taking the value “1” for farmers who have found the market reliable and “0” otherwise. Following Saleth (1996) and Meinzen-Dick (1998), the preferred logit model has been formulated as follows.

The logit model postulates that P_i , the probability that i^{th} farmer has found the groundwater market reliable is a function of an index variable Z_i (i.e. potential for reliability) summarising a set of explanatory variables X_{ki} . That is,

$$P_i = f(Z_i) = f\left(\alpha + \sum \beta_k X_{ki}\right) = \frac{1}{1 + e^{-z_i}} = \frac{1}{1 + e^{-\alpha + \sum \beta_k X_{ki}}}$$

Where,

Z_i = An underlying and unobserved index for the i^{th} farmer (when Z exceeds some threshold Z^* , the farmer is observed to be finding the market reliable for him).

X_{ki} = The k^{th} explanatory variables for the i^{th} farmer that may affect reliability of groundwater markets for irrigation.

$i=1, 2 \dots N$; where, N is the total number of sample farmers included in the analysis.

$k=1, 2 \dots M$; where M is the total number of explanatory variables.

α = Constant.

β = Vector of coefficients.

e = Base of the natural logarithm and approximately equals to 2.718.

Now, in estimation context Z_i can be estimated as follows (details are provided in section 6.1 of Chapter six);

$$\log\left(\frac{P_i}{1-P_i}\right) = z_i = \alpha + \sum \beta_k X_{ki} \dots (7.1)$$

Z_i is equal to the natural logarithm of the odd ratio i.e. the ratio of probability that the farmer has found the groundwater market reliable to the probability that the farmers have not found the market reliable.

The goodness of fit test describes how well a model fits to a set of observations. The goodness of fit of the model is evaluated with the help of Likelihood Ratio Test and pseudo coefficient of determination (pseudo R^2). In order to assess individual effect of explanatory variables on the dependent variables, marginal effects and elasticity coefficients are estimated. Both the coefficients are interpreted in the same manner as discussed in section 6.1 of chapter six.

Incorporating the explanatory variables discussed in section 7.3, the functional form of the model to be estimated has been specified as follows:

$$Z_i = \alpha + \beta_1(OFS) + \beta_2(ARAB) + \beta_3(TPFUE)l + \beta_4(DPTHB) + \beta_5(SSI) + \beta_6(EDN) + \beta_7(CSTE) + \beta_8(PSNR) + \beta_9(OTHS) + \beta_{10}(PRICE) + \beta_{11}(TNCY) + \beta_{12}(CORK) + \beta_{13}(KFC) + \beta_{14}(KOS) + U_i \dots (7.2)$$

U_i = the error term.

The maximum likelihood estimates of the model specified in Equation 7.2, have been obtained using STATA 11.0.

7.5 Results and Discussion:

The maximum likelihood estimates of the coefficients of the logit regression model, marginal effects and elasticity coefficients are presented in Table 7.5.

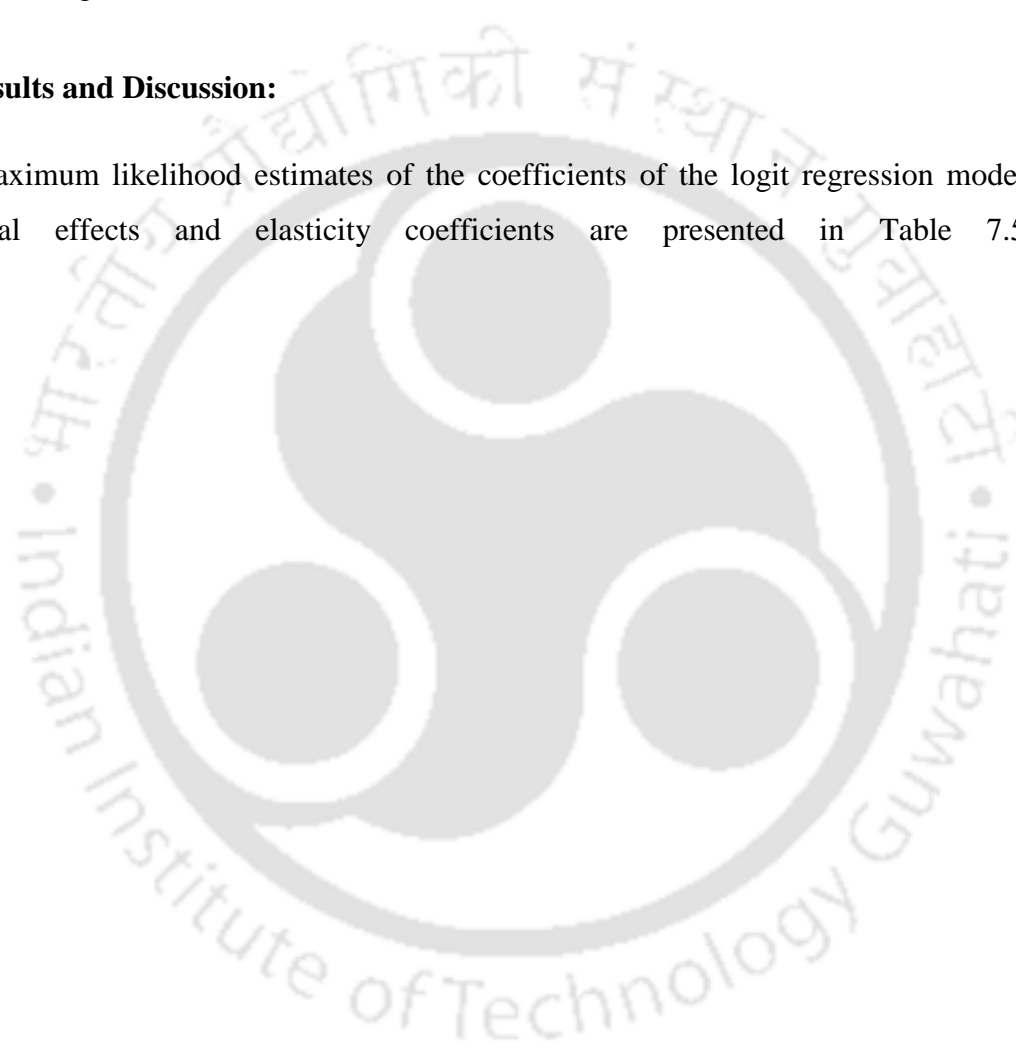


Table 7.5

Logit Estimates for the Likelihood of Groundwater Market to Become Reliable for the Sample Buyers

Variables	MLE estimates		Marginal effects		Elasticity
	Coefficients	Std. Error	dy/dx	Std. Error	ey/ex
<i>CONS</i>	1.437	1.570			
<i>OFS</i>	-0.334	0.239	-0.074	0.053	-0.20
<i>ARAB</i>	-2.209**	0.939	-0.492	0.197	-0.97
<i>TPFUEL</i>	-1.866**	0.779	-0.435	0.161	-1.02
<i>DPTHB</i>	0.020	0.012	0.004	0.003	0.89
<i>SSI</i>	0.038	0.522	0.009	0.117	0.01
<i>EDN</i>	-0.124***	0.064	-0.028	0.014	-0.37
<i>CSTE</i>	-0.636	0.585	-0.139	0.125	-0.18
<i>PSNR</i>	0.373	0.562	0.085	0.130	0.08
<i>OTHS</i>	-0.584	0.580	-0.126	0.121	-0.14
<i>TNCY</i>	0.847***	0.494	0.195	0.142	0.18
<i>CORK</i>	0.183	1.114	0.041	0.256	0.03
<i>PRICE</i>	0.002	0.000	0.000	0.000	0.02
<i>KFC</i>	0.724	1.134	0.160	0.246	0.24
<i>KOS</i>	0.301	1.219	0.068	0.281	0.06
Log-Likelihood Full Model			-53.3		
Log-likelihood Null Model			-64.482		
L-R Chi ²			22.365*		
Overall pseudo R ²			0.39		
Correct Prediction (in percent)			77.78		
McFadden's Adj. R ²			-0.059		
Crag & Huller's R ²			0.28		
Efron's R ²			0.215		
Adj. Count R ²			0.324		
Degrees of freedom			14		
Total observation			97		

*, ** and *** represent significance at 1 percent, 5 percent and 10 percent levels.

For a dummy variable, dy/dx is the discrete change of dummy from 0 to 1.

It is clear from Table 7.5 that the model presents a good fit as indicated by a highly significant Likelihood Ratio Test (LR-Chi²). The model has provided correct prediction to the extent of 77.78 percent of the dependent variable. The Variance Inflation Factors (VIF) values used to check multi-collinearity (shown in Table 7A.1 of Appendix-7.1), have shown absence of severe multi-collinearity problem in the model. The overall

pseudo coefficient of determination (pseudo R^2) has turned out to be 0.39. While the Mcfadden's adjusted R^2 has been found to be (-) 0.059, the adjusted count R^2 has been found to be 0.324. The significance and direction of change in the dependent variable with respect to change in each explanatory variable, marginal effects and the elasticity coefficient are discussed below.

Table 7.3 shows that the coefficient of "ARAB" is found to be highly significant and negative. This implies that when the quantity of groundwater purchased (measured in terms of buyers' cultivated area) increases the probability that a farmer finds the market reliable decreases. In other words, the reliability of the groundwater market for the buyers decreases when its' area under summer rice cultivation increases. Since an additional purchase of water requires more fuel, the buyers may not be able to buy the same, resulting in water being inadequate. As it is clear from the discussion of section 7.2 that about 36.67 percent of the buyers who have found the market unreliable due to their inability to buy diesel to operate the pumpsets, it is appropriate that the quantity of groundwater purchase has negative and significant influence on reliability of the groundwater market. The partial probability of the variable is found to be (-) 0.492 which implies that when "buyers' cultivated area" increases by one hectare, the probability of reliability decreases by 0.492 points. The elasticity coefficient of this variable indicates that one percent increase in the quantity of purchased groundwater results in 97 percent reduction in the probability of the groundwater market from its reliability.

Type of fuel has been considered as an important determinant of reliability of the groundwater market. The coefficient of this variable (*TPFUEL*) is found to be negative and significant. This implies that the chances of reliability of the groundwater market with diesel operated tubewell are lesser than the electricity operated tubewell. Despite the fact that electric tubewell is subject to the irregular and insufficient supply of electricity as pointed out by the sample farmers, the greater reliability with the electricity operated tubewell is worth investigating. Since the electric tubewell does not require the buyers to pay for the fuel for running the tubewell, it is not constrained by availability of funds at the time of irrigation requirement. This enables the buyers to get adequate amount of groundwater as per requirement of the crop. This finding is similar to Singh and Singh (2003) who in a study on reliability of water market has found

electricity operated tubewell is less reliable than the diesel operated tubewell. The partial probability of the variable is found to be (-) 0.435. This indicates that when water is bought from a diesel powered tubewell, the probability of reliability decreases by 0.435 points. The elasticity coefficient of the variable also indicates that *ceteris paribus*, when water is bought from a diesel operated tubewell, the probability of reliability decreases by 102 percent.

Tenancy as a variable is statistically significant and its coefficient is found to be positive. This implies that if a farmer is a tenant of the water seller, he is more likely to get an adequate supply of groundwater. This also implies that the groundwater market is strongly intertwined with the existing land tenure system making the practice relatively less reliable for non-tenant buyers. The partial probability of the variable is found to be 0.195. This implies that when a farmer becomes a tenant of the water seller, the probability of reliability of the market will increase by 0.195 points, other things remaining the same. The elasticity coefficient of this variable implies that if the farmer has a one percent chance of becoming a tenant of the water seller, the probability of the market to become reliable for him will increase by 18 percent.

The education of the head of the farm household has been found to have a negative influence on the likelihood of the groundwater market to become reliable for the buyer. Thus, though education may enhance the managerial capacity of the buyers-cum-farmers in terms of input use, etc., higher educational qualification may not guarantee reliability of the groundwater market in the adequate provisioning of groundwater for the buyers. The partial probability of the variable is found to be (-) 0.028. This implies that, *ceteris paribus*, when the education of a farmer increases by one year of formal schooling, the probability of reliability is decreased by 0.028 points.

In the available literature it is found that along with the market factors, the operation of groundwater markets is also influenced by presence of personal relationships between water buyers and sellers. However, in the present study, the coefficient of the variable personal relationship of the buyers with the corresponding water sellers as a determinant of reliability is found to be insignificant but bears a positive sign. Similarly, the role of other variables like cash transaction, output-sharing kind payment and kind payment (fixed) are found to be positive, though not significant in the context of the present study. Similarly, the coefficient of the variable “caste” is found to be

negative though not a significant determinant of reliability. In addition, other services required to be rendered by the buyers is also not a significant determinant of reliability of the market.

7.6 Summing Up:

It is clear from the above discussion that groundwater market is relatively unreliable for the buyers than the sellers. As high as 62 percent of the sample buyers have reported that the market is unreliable for them. Among the reasons cited by them for unreliable supply of water, the inability of the buyers to buy fuel to operate the pumpsets and presence of multiple buyers against a single seller are the two main reasons. However, a majority of farmers could not point out any specific reason for the non-reliability of the market for them. The logit analysis has shown that quantity of groundwater purchase (in terms of buyer's cultivated area under summer rice), education, tenancy and types of fuel/power used to operate the pumpsets are some significant determinants of reliability of groundwater market in the study area. The fact that groundwater market is intertwined with the existing land tenure system is established as about 29.29 percent of the tenant buyers have found the market reliable and tenancy as a factor has largely contributed to higher probability of reliable groundwater market.

Since as high as 62 percent of the sample buyers have not found the market reliable, the supply of assured irrigation to their crop fields is adversely affected. This might have a negative impact on the production and productivity of the crop undertaken for cultivation by the buyer-cum-farmer. This, in turn, may influence technical efficiency on their plots. Thus, technical efficiency on buyers' plots may be lower than that on sellers' plots. On the contrary, the efficiency principle of market suggests that buyers' plots are technically more efficient as they undertake cultivation with purchased water (Khanna, 2006). Besides, as discussed in Chapter five, there are differences in the application of other inputs in the cultivation of summer rice along with irrigation between the buyers and sellers. This has motivated us to examine the issue of technical efficiency on cultivated plots across various categories of groundwater users with or without participation in the market. The issue of technical efficiency and its different aspects is taken up for a detailed discussion in the next chapter.

Appendix-7.1

Collinearity Diagnostics for Independent Variables Influencing Reliability of Groundwater Markets

Table A7.1: Collinearity Diagnostics for Independent Variables Influencing Reliability of Groundwater Markets

Variable	VIF	SRT VIF	Tolerance	R-Squared
<i>OFS</i>	1.36	1.16	0.74	0.26
<i>ARAB</i>	1.32	1.15	0.76	0.24
<i>TPFUEL</i>	1.53	1.24	0.65	0.35
<i>DPTHB</i>	1.42	1.19	0.70	0.30
<i>SSI</i>	1.16	1.08	0.86	0.14
<i>EDN</i>	1.43	1.20	0.70	0.30
<i>CSTE</i>	1.44	1.20	0.69	0.31
<i>PSNR</i>	1.21	1.10	0.83	0.17
<i>OTHS</i>	1.33	1.15	0.75	0.25
<i>TNNCY</i>	1.33	1.15	0.75	0.25
<i>CORK</i>	3.51	1.87	0.29	0.71
<i>PRICEPERHECT</i>	1.30	1.14	0.77	0.23
<i>KFC</i>	4.72	2.17	0.21	0.79
<i>KOS</i>	4.55	2.13	0.22	0.78
Mean VIF	1.97			

Notes: There are many recommendations for acceptable levels of VIF. While the most commonly suggested maximum level of VIF is 10 (Kennedy, 1992), a recommended maximum VIF value of 5 and even 4 have also been found in the literature. Considering the most commonly used VIF value of 10, the presence of collinearity in preferred model has been checked.



CHAPTER EIGHT

TECHNICAL EFFICIENCY OF FARMS UNDER GROUNDWATER MARKETS

In chapter seven, reliability of groundwater market has been examined. The factors contributing to reliability of the market has been examined by applying a logit regression model. It has been found that due to the residual nature of the market, as high as 62 percent of the sample buyers have found the market unreliable for them. Since reliability affects timely and adequate/assured application of groundwater to the crop field, this might have an adverse impact on productivity of other inputs and thus, production of the crop undertaken by the buyers (Banerji et al., 2006). As discussed in chapter five, there are also differences in input intensities and in yield of the crop between the buyers and sellers. This indicates that there might have a difference in the attainment of technical efficiency between the buyers and sellers' plots. Moreover, Khanna (2006) notes that as many market and non-market factors enter into contract between buyers of water and the owners-cum-sellers of water, water use efficiency is bound to vary across various market players.

Therefore, it is important to investigate whether groundwater use is efficient for the farmers in the study area. The efficiency, viewed in this context, has two aspects, viz. allocative efficiency and technical efficiency. Though it is important to look at allocative efficiency of groundwater use, the issue could not be measured properly. For allocative efficiency, the value of marginal physical product of water (groundwater in the context of the present study) should be equal to its price (Khanna, 2006; Chowdhury, 2010). In other words, allocative efficiency occurs when the marginal rate of substitution between inputs equals the corresponding input price ratio (Mastromarco, 2008). Though the value of marginal physical product of any input can be estimated from the production function¹, the present study has been confronted with the difficulty in getting exact price for groundwater as such. This has arisen because it is found in the field that the farmers do not pay for water. The farmers pay for pumping groundwater which is the expenditure on energy and a payment to the tubewell owners-cum-sellers for using the pumpset. In fact, this is the normal practice in water transaction under informal water market. Further, the payment of water charge is made for the whole season in cash or in kind or both cash and kind. Thus, the information on actual

groundwater usage is not available as the groundwater as such is not traded in the market. The farmers neither know exactly how much water they use to irrigate their crop fields nor the number of hours of irrigation from the tubewell. In view of these problems, the issue of allocative efficiency of groundwater use has not been taken up in the study. The present study specifically aims at examining technical efficiency of the farms using groundwater as a crucial input.

Owing to difference in input use and timely and adequate use of water (due to inherent unreliable nature of the market), there arises differences in the attainment of technical efficiency between buyers' and sellers' plots (Manjunatha et al., 2011a, 2011b) or between buyers' plots and owner's plots (Khanna, 2006). Similarly, due to the scarcity of water, both the buyers and sellers' plots may turn out to be technically inefficient (Srivastava et al., 2009). Since market induces efficient use of resources, there might be a situation where buyer and seller's plots can be technically more efficient than the self-user's plots. Therefore, in the present chapter, the main objective is to examine technical efficiency of farms under different structures of groundwater markets. In an attempt to examine technical efficiency of farms, the study seeks to explore (i) whether there is any difference in technical inefficiency in the cultivation of summer rice (considered in the study) under different structures of groundwater market, (ii) is there any difference in technical efficiency among different categories of farmers? Or to identify to what extent it is possible to raise output by improving efficiency with the existing input bundles and the available technology², and finally, (iii) if technical inefficiency exists, what are the possible sources of inefficiency? Thus, the objective of this chapter is to estimate the level of technical efficiency scores among the summer rice producing farmers across different structures of the groundwater market and to identify the factors influencing technical inefficiency in the production of summer rice.

The rest of this chapter is organised in seven sections. Section 8.1 discusses the concept of technical efficiency. Section 8.2 elaborates the estimation method for technical efficiency. In section 8.3, the detailed method under the Stochastic Frontier Approach (SFA) has been spelled out. The specification of frontier production function for empirical estimation has also been done in this section. Section 8.4 includes the discussion on the suitability of translog production function over Cobb-Douglas (C-D) production function. Section 8.5 discusses the suitability and validity of inefficiency

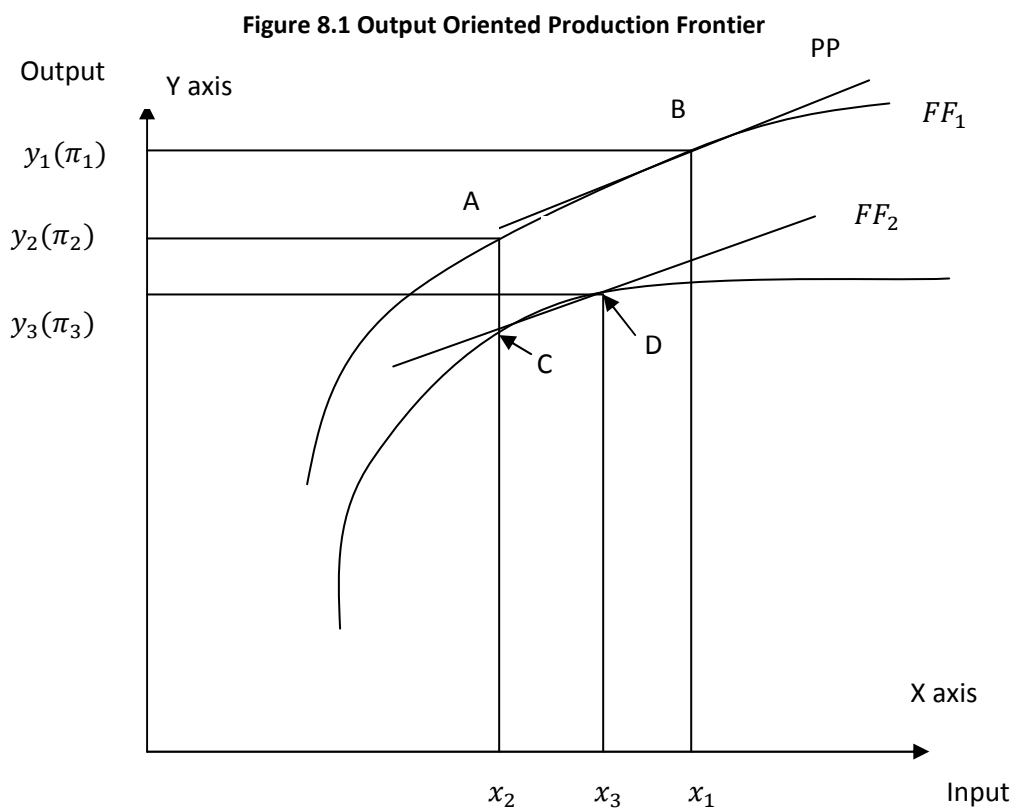
model. The results of stochastic frontier production inbuilt with inefficiency effects are presented and discussed in Section 8.6. Section 8.7 finally sums up the whole discussion of the chapter.

8.1 Concept of Technical Efficiency and the Production Frontier:

Technical efficiency refers to a situation where with a given technology and a set of inputs, a producer (a farm household in the study) is able to produce the maximum possible output. Technical efficiency is divided into two types: output oriented technical efficiency and input oriented or input conserving technical efficiency (Kalirajan and Shand, 1994, 1999). Output oriented technical efficiency is defined as the maximum output that can be produced for a given set of inputs. In other words, if a producer produces less than the maximum possible output then he is technically inefficient. Alternatively, input oriented technical efficiency measures the amount of minimum inputs required to produce a given level of output. That is, producers are regarded technically inefficient if they use more inputs than required to produce a given level of output. In the present study, the output oriented technical efficiency is estimated. The output oriented measure of technical efficiency has been attempted because the sample farmers have been found to be using a certain quantity of inputs (which is financially feasible) to get the maximum output. This is unlike the input oriented approach where the amount of output to be produced is targeted beforehand corresponding to variable amount of input.

Kalirajan and Shand (1994), notes that a profit maximising firm always tries to maximise production from a given set of inputs. Thus, production function which shows a technical relationship between input and output shows the maximum possible level of output that can be obtained for a given level of inputs. Alternatively, it implies that the function sets a limit, often known as production frontier, to the range of possible observations. Thus, for example, one may observe points below the production frontier (firms producing less than maximum possible output) but no points can lie above the production frontier. The amount by which a firm lies below its production frontier, and the amount by which it lies above its cost frontier, can be regarded as measures of inefficiency (Forsund et al., 1980). A firm is said to be efficient if it operates on the production frontier (Ali and Byerlee, 1991). This concept

of production frontier and technical efficiency can be illustrated with the help of Figure 8.1.



Source: Kalirajan and Shand (1994, 1999) and Kumbhakar and Lovell (2000).

In Figure 8.1 output (y) is measured along the Y-axis and the input (x) is measured along the X-axis. FF_1 is the production frontier for a firm using best practice for production. A firm operating at point B on FF_1 using x_1 of inputs and producing y_1 of output receives a profit π_1 . B is the point of tangency with its price line PP on its frontier FF_1 . At this point, the firm is economically efficient and there is neither technical nor allocative inefficiency. However, if the firm operates at point A on its frontier FF_1 using x_2 inputs and producing y_2 output, the profits will be π_2 . π_1 is greater than π_2 which is arising due to allocative inefficiency given by $\frac{\pi_2}{\pi_1}$. In reality, however, firms happen to operate at less than potential technical efficiency owing to a number of constraints such as inappropriate or outdated method of production, organisational constraints, non-price factors such as information glitches and incomplete knowledge of the best technical practices (Kalirajan and Shand, 1994; Khanna, 2006). In such a situation, the firm will operate on an actual or perceived

production frontier FF_2 which lie below the potential frontier. If the firm with x_2 inputs operate at point C on FF_2 it produces y_3 output and receives profit π_3 . At point C the firm experiences both technical and allocative efficiency. A movement to a point of production at D would leave the firm allocatively efficient but still technically inefficient as output level could be raised further to a level at frontier FF_1 . In terms of output loss for operating at point C, $(y_1 - y_3)$ is the loss in economic efficiency, of which a loss of $(y_2 - y_3)$ is due to technical inefficiency and $(y_1 - y_2)$ is due to allocative inefficiency.

8.2 Technical Efficiency and Estimation Methods:

The approaches used to estimate technical efficiency, can be categorised into two types: parametric and non-parametric. Parametric approach involves the Stochastic Frontier Analysis (SFA) and the Corrected Ordinary Least Square (COLS) whereas the non-parametric approach includes the Data Envelopment Analysis (DEA). The difference between the parametric and non-parametric approach lies in the assumption made about the functional form, whether or not random errors have been accounted for and the probability distribution assumed for the inefficiency (Kibarra, 2005). While parametric methods are restricted to a functional form, non-parametric methods rely solely on sample observations that are used to construct a production frontier (Khanna, 2006). Non-parametric methods, as originally conceived by Farrell (1957) used single input-output space to create a frontier isoquant within the production possibility set which has been later applied to the multiple input-output cases (Murillo-Zamorano, 2004). Khanna (2006) also notes that the frontier is determined by a single or a convex combination of efficient units which are then compared against inefficient units to calculate the extent of inefficiency.

Parametric techniques can be separated into deterministic and stochastic methods. The difference between the deterministic and stochastic methods lies in the treatment of the error term. In deterministic methods, the error is implicitly assumed and makes no distinction between unobserved variables which is beyond the control of the agent and those that lie within it. Thus, it assumes that any deviation from the frontier function is due to inefficiency. Stochastic models on the other hand, decompose the error term into

purely statistical noise (that lies outside the control of the production agent) and inefficiency (a one-sided error term).

Farell (1957) is the pioneer of deterministic methods which was further developed and applied by Aigner and Chu (1968), Afriat (1972), Richmond (1974). Later on, Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977) proposed the model independently and used in the estimation of technical efficiency. Subsequently, their model has been applied by researchers like Abdulai and Huffman (2000) on rice farmers in Northern Ghana, Bravo-Ureta and Evenson (1994) on peasant farmers in eastern Paraguay, Chen and Huffman (2006) using a county-level dataset of China, and Xu and Jeffrey (1998) on a cross-section of Chinese farm households, Zhuo Chen (2009) on farm level TE from four regions of China; Zinan and Zhuang (2000), Xue-yuan (2010) and Tian and Wan (2000) in China; Kalirajan and Flinn (1983), Lingard, Castillo and Jayasuriya (1983), Kalirajan(1984), Dawson and Lingard (1989) in rice farming in the Philippines and many others.

The techniques used to estimate the efficiency frontiers can be categorised into two classes: mathematical programming techniques and econometric estimation methods. While mathematical programming techniques are mainly used in deterministic parametric methods, the stochastic parametric methods use only econometric techniques such as Maximum Likelihood Methods or Corrected Ordinary Least Squares (COLS) to estimate efficiency frontier (Aigner and Chu, 1968; Kumbhakar and Lovell, 2000). The Data Envelope Analysis (DEA) primarily uses mathematical programming to construct a production frontier in order to calculate efficiency scores. The advantage of DEA method lies in its flexibility as it does not require specification of any functional form. Hence, it is less prone to mis-specification as pointed by Yu (1998). Therefore, the fundamental problem associated with deterministic frontier is that any measurement error and any other source of stochastic variation in the dependent variable are included in the one-sided component. As a consequence, outliers can have profound effects on the estimates and any shortcoming in the specification of the model could translate into increased inefficiency measures (Greene, 1990).

There is an ongoing debate whether deterministic methodologies such as Data Envelopment Analysis (DEA) or stochastic methodologies such as the Stochastic Frontier Analysis (SFA) should be used in the estimation of technical efficiency

(Bravo-Ureta and Rieger, 1990). However, in the literature on agricultural economics, the SFA approach has generally been preferred because of its relevance in agricultural production (Coelli and Battese, 1996). Furthermore, the assumption that all deviations from the frontier are associated with inefficiency as assumed in DEA, is difficult to accept in case of agricultural production. Khanna (2006) also notes that agriculture is often susceptible to the vagaries of nature which is beyond control of a farmer. In the present study, groundwater availability (under the market structure) is a highly stochastic input to owner-cum-sellers due to relative scarcity of water during peak demand periods and especially to buyers due to unreliable nature of the market (discussed in details in chapter seven). There is also measurement error arising due to non-keeping of accurate records by many farmers as in the large number of cases they are small family owned operations (Coelli and Battese, 1996). At the same time, Thiam, Bravo-Ureta and Rivas (2001) provided a meta-analysis, reviewing empirical estimates of technical efficiency in agriculture in developing countries and found that stochastic versus deterministic frontiers do not seem to significantly affect estimates of technical efficiency across studies. However, parametric methods such as the stochastic production frontier method offer an opportunity to researchers to test their hypotheses, but restrict them to certain production relations assumed by the functional forms employed (Khanna, 2006).

In the present study, the SFA has been chosen in order to estimate technical efficiency of the sample farms. The selection is made because in addition to groundwater the production of summer rice in the state is subject to climatic conditions which are beyond control of the farmers. Therefore, unlike DEA, deviation from the best possible level of output cannot be entirely attributed to inefficiency. The method used is outlined in section 8.3.

8.3 Stochastic Frontier Approach (SFA):

8.3.1 The Stochastic Frontier Production Function and Technical Inefficiency:

Following Kalirajan and Shand (1994) the production frontier model for a firm producing a single output using multiple inputs can be written as,

$$Y_i^* = f(X_i, \beta) \dots (8.1)$$

Where,

Y_i^* = The maximum output that the firm can produce.

X_i = The vector of inputs that the firm can use to produce the maximum output given the technology.

β = The vector of technology parameter to be estimated.

The maximum output assumed in Equation (8.1) is obtained by the firm given the fact that the firm operates at the optimum level of technical efficiency employing available best practices. Thus, according to neoclassical economic theory, all firms are assumed to be fully efficient in the use of technology so that input and output prices are the only factors that decide output level (Kalirajan and Shand, 1994). Hence, any inefficiency that arises is attributable to price or allocative inefficiency. However, the firm may not be able to obtain the level of maximum output due to certain exogenous shocks such as socio-economic constraints, information gap and non-price factors, all of which may prevent them from utilising their inputs optimally (Khanna, 2006). In other words, the firms may experience technical inefficiency in production in the sense defined in the previous section 8.2, due to such exogenous shocks which are beyond their control.

Incorporating the element of technical efficiency the production function of the i^{th} firm defined in Equation (8.1) can be rewritten as (Kalirajan and Shand, 1994):

$$y_i = f(X_i, \beta) TE_i \quad \dots \quad (8.2)$$

TE_i represents technical efficiency of the i^{th} firm.

TE_i is the output oriented measure of technical efficiency and can be defined as,

$$TE_i = \text{Observed output} / \text{Maximum attainable output}$$

Or,

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{Y_i}{f(X_i, \beta)} \quad \dots \quad (8.3)$$

Y_i achieves its maximum feasible value of $f(x_i, \beta)$ if and only if $TE_i = 1$. $TE_i < 1$, implies presence of technical inefficiency in production. Thus, with technical inefficiency the firms operate below the maximum obtainable level of output.

In Equation (8.1) the production frontier is deterministic assuming that all factors affecting production are under the control of the firms. Hence, the deviation observed between the frontier and observed output levels is attributable to technical inefficiency. However, such kind of specification ignores the fact that output might also be affected by random shocks such as weather, information gap, socio-economic factors, extent of mechanisation, availability of groundwater (which is scarce in relative sense during the period of crop growth for the owners-cum-sellers and for a few buyers due to unreliable nature of the market), erratic and insufficient electricity supply, etc. which may or may not be under the control of the farms. In other words, the production frontier may become stochastic as a result of these random shocks. Incorporating these random shocks the stochastic production frontier can be re-specified as,

$$Y_i = f(X_i; \beta) \exp \{v_i\} \dots (8.4)$$

Thus, the stochastic production frontier consists of two parts a deterministic part $f(X_i; \beta)$ which is common to all producers and a producer specific part $\exp \{v_i\}$, which captures the effect of random shocks on each producer (Kumbhakar and Lovell, 2000). The technical efficiency of stochastic frontier model thus becomes,

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{Y_i}{f(X_i, \beta) \exp \{v_i\}} \dots (8.5)$$

Now Y_i achieves its maximum feasible value of $f(x_i, \beta) \exp\{v_i\}$ if and only if $TE_i = 1$, otherwise $TE_i < 1$ provides a measure of the shortfall of observed output from maximum feasible output (or termed as technical inefficiency) in the presence of random shocks which is allowed to vary across producers (Kumbhakar and Lovell, 2000).

Thus, in the presence of technical inefficiency the observed output may be defined as,

$$Y_i = f(X_i; \beta) \exp (v_i - u_i) \text{ with } u_i \geq 0 \dots (8.6)$$

Or

$$Y_i = f(X_i; \beta) \exp(\varepsilon_i) \dots (8.7)$$

Where, $\exp(\varepsilon_i = v_i - u_i)$ is the composite error term comprising of random noise v_i and pure technical inefficiency u_i . While v_i captures the measurement errors in production that the firm does not have control over them, u_i is associated with farm-specific factors

which leads to the i^{th} firm from not attaining maximum technical efficiency in production. Hence, u_i is labeled as technical inefficiency of the farms and ranges between zero and one. v_i is a symmetric error term that represent random variation of the frontier across farms and captures the effects of measurement error, statistical noise and exogenous random shocks which lie beyond control of the farm (Coelli and Battese 1996; Yu, 1998). v_i is identical and independently distributed. u_i represents the asymmetric and one sided non-negative random variable associated with technical inefficiency. u_i is also identical and independently distributed and is obtained as truncation at zero of the normal distribution. It is also assumed that v_i and u_i are uncorrelated. The condition $u_i \geq 0$ ensures that all observations lie on or below the stochastic production frontier. However, there is debate in the literature on technical efficiency estimation as there is no consensus on which distributional form whether normally distributed, exponential, truncated normal, and normal gamma be used. However, the half normal distribution has been widely preferred in most of the empirical studies on efficiency measurement (Khanna, 2006)³.

8.3.2 Variation in Efficiency Estimates across Farms and Factors influencing Technical Inefficiency:

Once we have the estimates for the efficiency scores across farmers, we may be interested to see the variation in inefficiency estimates. The existing literature points out that a number of possible factors may affect technical efficiency on a farmer's plots. These include like farm-specific characteristics, such as education and age of the farmer, experience in crop cultivation, extension help distance of the plot from the water source, discharge rate of the tubewell and area of land cultivated, etc. (Bravo-Ureta and Pinheiro, 1993; Khanna, 2006). The findings of the present study (discussed in Chapter five) also indicate that access to credit, off-farm income sources in the farm households and use of soil nutrients (micro nutrient/organic manure) may also contribute to variation in technical inefficiency across farmers.

In order to identify the determinants of technical inefficiency, the *TE* scores are regressed on the chosen explanatory variables that are likely to influence inefficiency. There are two approaches for obtaining the estimates of inefficiency models: two-stage approach and single stage approach. While two-stage approach were mainly used till a few years back, in the recent studies using SFA, there is an increasing preference for

single stage approach. Previous studies followed two-stage processes. Under two-stage approach, the first stage involved obtaining the inefficiency scores and in the second stage those inefficiency scores were regressed on a set of explanatory variables to determine the socio-economic characteristic that determine levels of technical inefficiency. But, this two-stage approach is considered inconsistent in its assumption regarding the independence of the inefficiency effects in the two stages estimation (Battese and Coelli, 1995). Under single stage approach, estimates of technical inefficiency are obtained along the stochastic production frontier model. Kumbhakar, Ghosh and McGuckin (1991), Reifshneider and Stevenson (1991), Huang and Liu (1994), Battese and Coelli (1995), etc. are the pioneers in using the single stage approach in their respective empirical studies. They have found the approach accurate from a statistical point of view. Single stage approach is expected to lead to more efficient inference with respect to the parameters involved (Battese and Coelli, 1996). In most of the recent studies, single approach is followed which is followed in our study as well.

The variations in inefficiency are, thus, modeled as a function of some of the farm-specific characteristics as,

$$U_i = \delta_0 + \delta_i Z_i + W_i \dots (8.8)$$

Where,

Z_i is a vector of explanatory variables associated with technical inefficiency

δ_i is the corresponding vector of parameters to be estimated.

W_i is a random error term and is defined by the truncation of u_i in Equation (8.7) such that $W_i - \delta_i Z_i$ which preserves the condition of $u_i \geq 0$.

Thus, the farm-specific technical efficiency of production, given the level of inputs, is given as:

$$TE_i = \exp(-U_i) \dots (8.9)$$

So that,

$$0 \leq TE_i \leq 1$$

$$\text{as } 0 \leq \exp(-U_i) \leq 1$$

That is, the farm-specific technical efficiency lies between 0 and 1 and is inversely related to the level of technical inefficiency.

8.3.3 The Empirical Stochastic Frontier Production Model with the In-built Technical Inefficiency Function:

The estimates of the parameters defined in Equation (8.7) can be obtained by specifying either the translog production function or the Cobb-Douglas (C-D) production function. A number of earlier studies have specified C-D production function for this purpose (Meeusen and Den Broeck, 1997; Tadesse and Krishnamoorthy, 1997; Sharma et al., 1999; Mochebelele, 2000; Belen et al., 2003; Shanmugam, 2003; Binam et al., 2004; Bozoglu and Ceyhan, 2007; Oyewo, 2011, etc.). However, pointing out the limitations of constant production elasticity and unit elasticity of input substitution assumed by C-D production function, a number of studies have applied a more flexible form given by translog production function (Huang and Bagi, 1984; Yu, 1998; Abdulai and Huffman, 1998, 2000, 2001; Wilson et al., 2001; Chen et al., 2009; Liu and Zhuang, 2000; Khanna, 2006; Chowdhury, 2009, 2010, etc.). In a few studies, the researchers have first estimated both the functional forms and then a hypothesis test is carried out to find suitability of the model to the given data set. For example, Seyoum (1998), Mochebelele (2000), Khanna (2006), Shanmugam and Venkataramani (2006) and Bozoglu and Ceyhan (2007), etc. in their studies on technical efficiency have found C-D production function more appropriate than the translog production function. On the other hand, Chiang et al. (2004), Kumbhakar and Wang (2006), Mussa (2006), Chowdhury (2010), etc. in their studies have found translog production function more appropriate than the C-D production function. Thus, there is no consensus on the best functional specification between the two. In the empirical study of Khanna (2006) estimating technical efficiency of farmers under water market using SFA, first translog production function has been specified and then it is tested against C-D production function. Khanna found C-D production function more appropriate given data set.

In the present study, to decide on the most suitable functional specification, a translog stochastic frontier model is first estimated then it is tested against a C-D production functional form. This study has specified the stochastic frontier production function using the flexible translog production function.

The general form of the translog model is as follows:

$$\ln Y_i = \beta_0 + \sum_{k=1}^N \beta_k \ln x_{ik} + \frac{1}{2} \sum_{k=1}^N \sum_{j=1}^N \beta_{jk} \ln x_{ik} \ln x_{ij} + v_i - u_i \quad \dots (8.10)$$

8.4 Description of Variables Considered in the Translog Production Function and Inefficiency Model.

8.4.1 Translog Production Function:

The available theoretical and empirical literature reflects on a number of factors that are considered for the specification of inbuilt production and inefficiency models in stochastic frontier analysis. However, subject to the availability of data and their relevance in the context of the present study, five key inputs for summer rice cultivation i.e. land, labour, capital, irrigation and fertiliser are included as input variables to estimate the translog production function. Thus, for the five inputs variables, viz. land, labour, capital, irrigation and fertiliser the study has specified the following form:

$$\ln Y_i = \beta_0 + \sum_{k=1}^5 \beta_k \ln x_{ik} + \sum_{k=1}^5 \sum_{j=1}^5 \beta_{jk} \ln x_{ik} \ln x_{ij} + v_i - u_i \dots (8.11)$$

The description of the variables considered in the translog production function and expected signs of the variables specified in Equation 8.11, are presented in Table 8.1.

Table 8.1
Description of the Variables in Translog Production Function and Expected Sign of the Coefficients of the Variables

Variable	Description	Expected sign
Output	Total output of the farm (in quintal)	Dependent variable
Land area	Land area under the crop (in hectare)	+
Labour	Total labour man-days (both family and hired labour)	+
Capital	Capital expenditure* (In rupees)	+
Total nos. of irrigation	Total quantity of irrigation (in number)**	+
Fertiliser	Total amount of fertiliser measured in nutrient (NPK) (in Kg.)	+
Lnland	Log of land area under the crop (in hectare)	+
Lnlabour	Log of total labour man-days (in man-days)	+
Lncapital	Log of total quantity of irrigation (in rupees.)	+
Lnirrigation	Log of capital expenditure (in rupees)	+
Lnfertiliser	Log of fertiliser measured in nutrient (NPK) (in Kg.)	+
(Inland) ²	log of land × log of land	+/-
(Inlabour) ²	log of labour × log of labour	+/-
(Incapital) ²	log of capital × log of capital	+/-
(Inirrigation) ²	log of irrigation × log of irrigation	+/-
(Innfertiliser) ²	log of fertiliser × log of fertiliser	+/-
(Inland)×(Inlabour)	log of land × log of labour	+/-
(Inland)×(Incapital)	log of land × log of capital	+/-
(Inland)×(Inirrigation)	log of land × log of irrigation	+/-
(Inland)×(Infertiliser)	log of land × log of fertiliser	+/-
(Inlabour)×(Incapital)	log of labour × log of capital	+/-
(Inlabour)×(Inirrigation)	log of labour × log of irrigation	+/-
(Inlabour)×(Infertiliser)	log of labour × log of fertiliser	+/-
(Incapital)×(Inirrigation)	log of capital × log of irrigation	+/-
(Incapital)×(Infertiliser)	log of capital × log of fertiliser	+/-
(Inirrigation)×(Infertiliser)	log of irrigation × log of fertiliser	+/-

* In the present context, the definition of capital confines only to the working capital. In other words, we have used capital as a flow concept rather than a stock. Thus, expenditures on capital include payment made in terms of rents of tractor, power tiller, bullock pair, harvester and sprayer. Expenditures incurred on the above items by a farm household constitute the total capital expenditures of that household. It may be mentioned here that to correct for the variations in the rents of capital items across field study locations, we have taken the average of rents prevailing in the two field study locations for each of the above items.

** Total quantity of irrigation is total nos. of irrigation per farm plot for the whole season of crop growth.

8.4.2 Inefficiency Model:

Based on available literature, the education of the head of the farm household (who takes major decision in farming), age of the head of the farm household, access to formal credit, availability of off-farm income sources in the farm household, farmer's

contact with the extension services given by the government, use of organic manure and use of micronutrient have been included for the specification of inefficiency model. Following is a brief discussion on the theoretical justification for inclusion of these variables in the inefficiency model.

Factors such as experience, knowledge and managerial skills are important for effective farming. In order to capture effects of these factors, the education and age of the head of the farm household, who takes major decisions in farming, are taken as proxy variables. Education enhances knowledge of a farmer on know-how of advanced farm practices, which directly helps in the enhancement of production and productivity. Hence, when a farmer is more educated, the farmer is rewarded with more technical efficiency or the farmer is closer to the frontier output. The coefficient of the variable is expected to assume negative sign meaning education is negatively related with technical inefficiency.

It is generally believed that when a farmer becomes older he gathers more experiences in farming. Thus, like education, age of a farmer also greatly affects timely and proper allocation of farm inputs to deduce maximum output from the input mix. Therefore, this variable is assumed to bear a negative relationship with technical inefficiency.

It is found in the field that the availability of off-farm income sources in the farm household is very important for effective farming especially for the cultivation of summer rice. This is due to several reasons: *firstly*, a farm household with a stable subsidiary source of income may enjoy capacity to invest on tubewell. Hence, a farmer can gain more control on the application of groundwater during the crucial periods of crop growth. *Secondly*, availability of off-farm income of the farm household also enables the farmer to buy other inputs like fertilisers, pesticides and weedicides. It also helps the farm household to mechanise farming which, in turn, enhances production of the crop under cultivation. Because of its significant role in effective farming, this variable is included in the model. The expected sign of the coefficient of the variable is negative. It implies that a farm household with subsidiary sources of income can attain more technical efficiency in the production of summer rice than the other. The variable off-farm income is constructed as a dummy variable assuming the value “1” if the farm household has off-farm income sources and “0” otherwise. The variable in short is denoted as *SSI*.

Similarly, access to formal source of credit enhances production and productivity as access to credit from formal sources enables a farmer to purchase capital inputs. Therefore, the variable is assumed to bear a negative relationship with technical inefficiency. The role of this variable (denoted in short as *ACIC*) is captured by a dummy which takes the value “1” if the farm family has access to credit and “0” otherwise.

Farmers’ contact with the government extension services also helps a farmer in the adoption of better farming practices. With this, the farm is expected to attain technical efficiency. In the questionnaire administered to collect primary data, nine questions related to farmers’ interaction with government extension services were included. Farmers’ responses to these queries were codified into scores. The total scores on these queries could vary from 0 to 9 depending on the level of farmers' interaction with the extension agencies (details are discussed in section 5.3.6 of chapter five). A farmer's scores on these questions have been used as the measure of his contact to extension service. The expected relationship between this variable and technical efficiency is positive indicating its negative influence on technical inefficiency.

It is found that there is an increasing tendency among the farmers in the study area to use some soil-nutrients like micronutrients in the production of summer rice. Therefore, use of micronutrient as a variable is included in the analysis to see its role in the enhancement of technical efficiency. The expected role of this variable on technical inefficiency is also negative as application of micro nutrient helps in the enhancement of soil nutrient which, in turn, increases production and productivity of the crop undertaken for cultivation.

Further, along with chemical fertiliser, the traditional practices of using organic manure in the form of cow dung and other crop residuals is very popular in the cultivation of rice in the state. The general expectation is that use of organic manure would help in the attainment of technical efficiency. Hence, the expected role of this variable on technical inefficiency is negative.

The definition of the explanatory variables included in the inefficiency model and their expected signs are presented in Table 8.2.

Table 8.2
Definition of the Variables Influencing Technical Inefficiency and the Expected Sign of the Coefficients of the Variables

Variables	Description	Expected sign
Age	Age of the head of the farm household (in years)	-
Education	Years of schooling attended by the head of the farm household (in years)	-
Off-farm income in the family	Presence of off-farm income source in the family (1 = Yes, 0 = No)	-
Access to credit	Access to formal credit (1 = Yes, 0 = No)	-
Extension services	Extension services received by the farmers (Score 0 to 9)	-
Organic Manure	Organic manure used in cultivation (1 = Yes, 0 = No)	-
Micronutrient	Micronutrient used in cultivation (1 = Yes, 0 = No)	-

8.4.3 The Descriptive Statistics of the Variables:

The descriptive statistics of the key variables which are included in the translog production function and the inefficiency model are presented in Table 8.3.

Table 8.3
Descriptive Statistics of the Variables Considered in Translog Production Function and Inefficiency Function

Variables	Mean	S.D.	Minimum	Maximum
Output (in quintal)	65.17	50.33	8.00	273.20
Land area (in hectare)	0.97	0.73	0.13	3.88
Labour(in man-days)	117.47	74.70	21.00	386.00
Capital (in rupees)	4817.19	3541.95	640.00	17860.00
Irrigation (in nos.)	12.34	2.63	6.00	20.00
Fertiliser(NPK in Kg)	168.74	174.18	11.50	1070.40
Age (in years)	47.12	11.71	22.00	75.00
Education (years of formal schooling)	5.10	4.86	0.00	15.00
Off-farm income in the family (Y/N)	1.54	0.50	0.00	1.00
Access to credit (Y/N)	0.16	0.36	0.00	1.00
Extension services (Scores)	2.48	3.04	0.00	9.00
Organic Manure(Y/N)	0.44	0.50	0.00	1.00
Micronutrient(Y/N)	0.32	0.47	0.00	1.00

The average production of summer rice is 65.17 quintals per farm household which is 68.89 quintals per hectare (discussed in details in section 5.3.5 of chapter five). It is found that the rice production is highly variable ranging from 8 quintals to a maximum of 273 quintals per farm household. A wide variation is also observed in land area taken up for cultivation by the farmers. The average land area under summer rice cultivation is 0.97 hectare per farm household. When the minimum is 0.13 hectares, the maximum land area is 3.88 hectares. Average capital expenditure is ₹ 4877.00 per farm household which is equivalent approximately to ₹ 5027.84 per hectare of land. The average labour use is approximately 121 man-days per hectare during the whole season in different stages of cultivation. The average number of irrigation (complete irrigation as per requirement felt by the farmer) is approximately 12 number for the whole season for the whole plots of land under the crop. The maximum number is 20 whereas the minimum quantity is 6. The average quantity of soil-nutrient measured in terms of NPK is 168.74 kg which is approximately 173.96 kg per hectare of land (details are discussed in section 5.3.4 of chapter five).

The average age of the head of the household is 47 years indicating that on average, the sample farmers belong to the upper side of the working age group of 25 to 60 years. The average years of formal schooling attended by the sample farmers is 5 years indicating that they are primary passed. The minimum is “0” indicating they are illiterate. The maximum year of formal schooling is 15 implying that they are postgraduate. The majority of the farmers are illiterate and those who are literate are primary passed only (discussed in details in section 4.6.4 in chapter four). The variable off-farm income in the family is a dummy variable. More than 46.60 percent of the total farm households are engaged in income generating activities outside the farm. Similarly, access to formal credit is also a dummy variable. Out of the total sample only 24.24 percent have access to formal credit (discussed in details in section 5.4.1 of chapter five). Out of the total sample farmers, 44 percent have used organic manure in the cultivation of summer rice along with chemical fertilisers and 32 percent have used micronutrient for the cultivation of the summer rice. The interaction with the extension services is recorded in terms of score in the same line outlined in section 5.3.6 of chapter five.

Thus, the empirical full model (production function and inefficiency model) is specified as:

$$\begin{aligned} \ln Y = & \beta_0 + \beta_1 \ln land + \beta_2 \ln labour + \beta_3 \ln irri + \beta_4 \ln capital + \beta_5 \ln fert + \beta_6 \ln land^2 + \beta_7 \ln labour^2 \\ & + \beta_8 \ln irri^2 + \beta_9 \ln capital^2 + \beta_{10} \ln fert^2 + \beta_{11} \ln land * \ln labour + \beta_{12} \ln land * \ln capital \\ & + \beta_{13} \ln land * \ln irri + \beta_{14} \ln land * \ln fert + \beta_{15} \ln labour * \ln capital + \beta_{16} \ln labour * \ln irri \\ & + \beta_{17} \ln labour * \ln fert + \beta_{18} \ln capital * \ln fert + \beta_{19} \ln capital * \ln irri \\ & + \beta_{20} \ln irri * \ln fert + \delta_0 + \delta_1 education + \delta_2 age + \delta_3 ssi + \delta_4 acic + \delta_5 extension \\ & + \delta_6 organic + \delta_7 micronutrient + v_i - u_i \dots \dots \dots (8.12) \end{aligned}$$

Where,

v_i = random noise and $v_i \sim N(0, \sigma_v^2)$.

u_i = inefficiency effects, which are non-negative and follow a half normal distribution; $u_i \sim |N(0, \sigma_u^2)|$.

The first section of Equation 8.12 is the stochastic frontier translog production function while the second section includes the inefficiency variables.

The parameters of the translog stochastic frontier and the inefficiency model, defined in Equation 7.12 are estimated using the programme FRONTIER Version 4.1 (Coelli, 1996). That is, β_i, δ_i , the variance parameters $\sigma^2 = (\sigma_v^2 + \sigma_u^2)$ and $\gamma = \frac{\sigma_v^2}{\sigma_v^2 + \sigma_u^2}$ are estimated by the maximum likelihood procedure. The value of the parameter γ , lies between 0 and 1.

8.5 Choosing between Translog versus C-D Production Function:

Results of the statistical test carried out to find out suitability of C-D production function versus translog production function, have been discussed in this section. In the studies on technical efficiency, a number of tests like Log-likelihood Ratio Test or Wald Test or F- Test is used in order to verify suitability of the forms of production function. Among others, the generalised Log-likelihood Ratio Test is more popularly used by the researchers. In the present study, the generalised Log-Likelihood Ratio test is used which is defined as given below,

$$\lambda = -2 \left[\ln \frac{LLF_0}{LLF_1} \right] = -2 [\ln (LLF_0) - (\ln LLF_1)] \dots (8.13)$$

In equation (8.13), $\ln(LLF_0)$ is the log-likelihood value for the restricted or Cobb-Douglas production function and $\ln(LLF_1)$ is the log likelihood value for the unrestricted or translog production function. In a large sample, the test statistic λ follows a chi-square (χ^2) distribution with the number of degrees of freedom equal to the number of restricted parameters in the model (Green, 2003). The null hypothesis is rejected when the calculated value of χ^2 exceeds the tabulated value. The tabulated value for (χ^2) corresponding to the degrees of freedom is read from Kodde & Pam (1986) table.

The maximum likelihood estimates of the parameters of the stochastic frontier production function and the farm specific estimates of technical inefficiency have been obtained by using the programme FRONTIER version 4.1 (Coelli, 1996).

In the translog production function specified in equation 8.12, if we impose restriction on the second order and cross product terms, we obtain the restricted or Cobb-Douglas production function. That is, when, $\beta_{jk} = \beta_{ik} = 0 \forall i, k$

$$\ln y_i = \beta_0 + \sum_{k=1}^N \beta_k \ln x_{ki} + v_i - u_i \dots (8.14)$$

Thus, the null hypothesis for testing suitability of translog specification is,

$$H_0: \sum_i \beta_{jk} = 0 \forall j, k = 1 \dots j$$

From the estimates of restricted and unrestricted models, the log likelihood ratio test is obtained as,

$$\begin{aligned} \lambda &= -2 \left[\ln \frac{LLF_0}{LLF_1} \right] = -2 [\ln(LLF_0) - \ln(LLF_1)] \\ &= -2(48.59 - 63.41) = 29.61 \end{aligned}$$

The calculated chi-square ($\chi^2=29.61$) has exceeded the critical value of $\chi^2 = 24.384^4$ at 5 percent level of significance. Thus, the log likelihood ratio test rejects the null hypothesis and indicates that the sample and the model being analysed are found to be better represented by the translog production function than the production function of C-D type. Therefore, in the present study results of the production estimates, technical efficiency scores and determinants of inefficiency have been discussed using the estimates of translog production function.

The translog production function is then tested for detection of the presence of heteroscedasticity. This is done by running a regression of the dependent variable (log of output) on the input (or explanatory) variables considered in the translog production function. Both Breusch-Pagan test and White test have been obtained using STATA version 11.1 for checking heteroscedasticity. Test statistics of both the tests have been found to be insignificant confirming that the problem of heteroscedasticity is not present in the data set used for estimating the translog production function⁵.

8.6 Suitability and Validity of the Inefficiency Model:

In order to test suitability of the preferred frontier model incorporating inefficiency effects, four tests have been carried out. These tests are performed with the following hypotheses using the generalized Log-likelihood Ratio Test outlined in section 8.5.

- a. Hypothesis for no inefficiency effects:

Null hypothesis, $H_0: \gamma = 0$

- b. Hypothesis for absence of technical inefficiency effects:

Null hypothesis, $H_0: \gamma = \delta_0 = \delta_1 = \dots = \delta_7 = 0$

- c. Hypothesis for absence of constant and farm specific factors:

Null hypothesis $H_0: \delta_0 = \delta_1 = \dots = \delta_7 = 0$

- d. Hypothesis for joint significance of the explanatory variables for explaining efficiencies:

Null hypothesis, $H_0: \delta_1 = \dots = \delta_7 = 0$

Results of the hypothesis tests for the stochastic translog production function and inefficiency model are presented in Table 8.4.

Table 8.4
Hypothesis Tests for the Stochastic Translog Production Function and Inefficiency Model

Null hypothesis	LR statistic	Degrees of freedom	Critical value	Decision
$H_0: \gamma = 0$	2.79	1	2.706*	Reject
$H_0: \gamma = \delta_0 = \delta_1 = \dots = \delta_7$	35.422	9	16.274*	Reject
$H_0: \delta_0 = \delta_1 = \dots = \delta_7$	33.109	8	17.670*	Reject
$H_0: \delta_1 = \dots = \delta_7 = 0,$	27.49	7	14.853*	Reject

* Significant at 5 percent level. The statistic λ follows a mixed chi-square distribution because the test involves equality and inequality ($\gamma > 1$) restriction. Values are taken from Kodde and Palm (1986).

The first null hypothesis explores whether each farm is operating on the technically efficient frontier. If inefficiency effects are not stochastic, then γ or variance of inefficiency is zero⁶. This is rejected in favour of the presence of inefficiency effects. It also indicates that inefficiency effects are stochastic.

The second hypothesis is performed to test the absence of technical inefficiency effects. The null hypothesis is rejected which implies that output on farmers' plots are below their output-oriented technically efficient frontier.

As a variant to the second hypothesis, a third test is conducted to assess whether constant and farmer specific effects in the error component is present or not. The test results reject the null hypothesis in favour of inclusion of these variables in the model.

The fourth hypothesis explores the joint significance of the determinants of inefficiency. The null hypothesis is rejected confirming that joint effects of the explanatory variables included in the model influence technical efficiency of the farms even though when taken individually some of them may not be statistically significant.

8.7 Results and Discussion:

8.7.1 Production Estimates:

The maximum likelihood estimates of the parameters of stochastic frontier model with inefficiency effects are presented in Table 8.5.

Table 8.5
Maximum-likelihood Estimates for Parameters of Translog Stochastic Frontier and Inefficiency Model

	Parameters	Cobb-Douglas		Translog	
		Coefficient	S.E.	Coefficient	SE
Production function					
Constant	β_0	1.792*	(0.482)	-21.848*	(0.999)
Lnland	β_1	0.553*	(0.082)	-7.298*	(0.800)
Lnlabour	β_2	0.161*	(0.048)	1.777***	(0.961)
Lncapital	β_3	0.098**	(0.043)	2.073**	(0.714)
Lnirrigation	β_4	0.160*	(0.054)	4.022*	(0.897)
Lnfertiliser	β_5	0.044	(0.032)	1.473***	(0.877)
(Inland) ²	β_6			-0.553*	(0.153)
(Inlabour) ²	β_7			0.305**	(0.118)
(Incapital) ²	β_8			0.129*	(0.079)
(Inirrigation) ²	β_9			0.073	(0.155)
(Innfertiliser) ²	β_{10}			0.011	(0.028)
(Inland)×(Inlabour)	β_{11}			0.071	(0.205)
(Inland)×(Incapital)	β_{12}			0.567*	(0.157)
(Inland)×(Inirrigation)	β_{13}			0.368	(0.256)
(Inland)×(Infertiliser)	β_{14}			0.259***	(0.156)
(Inlabour)×(Incapital)	β_{15}			-0.437*	(0.133)
(Inlabour)×(Inirrigation)	β_{16}			-0.040	(0.165)
(Inlabour)×(Infertiliser)	β_{17}			-0.197***	(0.116)
(Incapital)×(Inirrigation)	β_{18}			-0.487**	(0.162)
(Incapital)×(Infertiliser)	β_{19}			-0.010	(0.120)
(Inirrigation)×(Infertiliser)	β_{20}			-0.124	(0.161)
Inefficiency Model					
Constant	δ_1	-2.569**	(1.156)	-1.252**	(0.545)
Age	δ_2	0.031**	(0.013)	0.015**	(0.005)
Education	δ_3	0.115**	(0.047)	0.071**	(0.026)
Off-farm income	δ_4	-0.457**	(0.190)	-0.114***	(0.068)
Access to credit	δ_5	0.146	(0.138)	0.218***	(0.131)
Extension	δ_6	-0.055***	(0.023)	-0.030**	(0.014)
Organic manure	δ_7	-0.091	(0.091)	-0.212**	(0.118)
Micronutrient	δ_8	0.274**	(0.105)	-0.001	(0.077)
σ^2		0.130*	(0.035)	0.047*	(0.009)
γ		0.822*	(0.067)	0.547*	(0.113)
Log likelihood function		62.43		79.92	
Mean technical efficiency (in percent)		92.46		94.10	

*, ** and *** are significant at 1 percent, 5 percent and 10 percent level.

The estimated value of the γ parameter which is a measure of the level of technical inefficiency effects in stochastic frontier is found to be 0.55 in translog production function. The value of γ ranges between 0 and 1. A value closer to 1 implies that random variation in the frontier is highly explained by inefficiency, while a value closer to zero implies absence of technical inefficiency. The estimated value of 0.55 which is highly significant implies that about 55 percent of the random variation in summer rice production of the sample farmers is explained by inefficiency.

It is evident from Table 8.6 that the estimates of the parameters of the first order terms of the translog production function indicate that with the exception of land all other input variables show a positive relation with the output. All the inputs \ln land, \ln labour, \ln capital, \ln irrigation and \ln fertiliser have been found to be significant. The expected sign of the input variables are also found to be in accordance with the a priori assumption except for \ln land.

Regarding second order coefficients, doubling of labour and doubling of capital are significant and positively related with the output. Though the coefficient of $(\ln$ land)² is significant, it is negatively related with the output. This implies other factors remaining same, doubling of land area would result in decline in output. However, if land is combined with fertiliser and capital then output is enhanced, as the second order cross product terms are significant and the coefficients have positive sign.

Regarding second order coefficients, the cross products of labour and irrigation and labour and capital are highly significant but their impacts are negative. Similarly, the coefficient of cross product of capital and irrigation is also negative though significant at one percent.

The estimates of parameters in a production function give only the direction of change in output with respect to the corresponding inputs. In order to understand how output responds to inputs we have to look at the elasticity coefficients (Abdulai and Eberlin, 2001). As opposed to the Cobb-Douglas production function, the coefficients of the translog production in a translog production function are the elasticity coefficients for the individual variables when the variables are evaluated at their sample mean (Vilanu and Fleming, 2004). Therefore, in order to compute elasticity estimates, firstly variables are mean corrected by subtracting the means of the variables so that their

averages or sums are zero. Secondly, estimates of the translog production function for the variables when they are mean corrected, are obtained using the computer program FRONTIER version 4.1 (Coelli, 1996). Though the estimates of the first order parameters are the estimates of output elasticity for the individual inputs at the mean values, the first order-coefficients of the translog production function are not very informative (Vilanu and Fleming, 2004; Abdulai and Eberlin, 2001). Following Abdulai and Eberlin (2001) the output elasticity with respect to the inputs X_j , for the translog production function are computed as,

$$e_j = \frac{\partial \ln Y_i}{\partial \ln X_i} = \beta_j + \sum_{j=1}^5 \beta_{jk} \ln X_j \dots \quad (8.15)$$

For example, in the translog production function specified for empirical investigation in this study,

$$\begin{aligned} \ln Y = & \beta_0 + \beta_1 \ln land + \beta_2 \ln labour + \beta_3 \ln irri + \beta_4 \ln capital + \beta_5 \ln fertliser + \beta_6 \ln land^2 + \beta_7 \ln labour^2 \\ & + \beta_8 \ln irri^2 + \beta_9 \ln capital^2 + \beta_{10} \ln fertliser^2 + \beta_{11} \ln land * \ln labour + \beta_{12} \ln land * \ln capital \\ & + \beta_{13} \ln land * \ln irri + \beta_{14} \ln land * \ln fertliser + \beta_{15} \ln labour * \ln capital \\ & + \beta_{16} \ln labour * \ln irri + \beta_{17} \ln labour * \ln fertliser + \beta_{18} \ln capital * \ln fertliser \\ & + \beta_{19} \ln capital * \ln irrigation + \beta_{20} \ln irrigation * \ln fertliser, \end{aligned}$$

$$\text{Elasticity of land} = e_{land} = \frac{\partial \text{Output}}{\partial \text{land}} \times \frac{\text{land}}{\text{Output}}$$

$$\frac{\partial \ln Y}{\partial \ln land} = (\beta_1 + 2\beta_6 + \beta_{11} + \beta_{12} + \beta_{13} + \beta_{14}) \frac{\text{Output}}{\text{land}}$$

$$\Rightarrow e_{land} = (\beta_1 + 2\beta_6 + \beta_{11} + \beta_{12} + \beta_{13} + \beta_{14})$$

(Details of the derivation is given as endnote)⁷

The input elasticity for each input in the translog stochastic production function including inefficiency effects is presented in Table 8.6.

Table 8.6
Input Elasticity

Variable input	Elasticity
Land ⁸	-7.35
Labour	1.43
Capital	3.28
Irrigation	3.21
Fertiliser	0.99

It is evident from Table 8.6 that a one percent increase in capital expenditure would increase output by 3.28 percent. In addition, a one percent increase in labour man-days will increase output by 1.43 percent. On the other hand, a one percent increase in the number of irrigation will increase output by 3.21 percent. The elasticity coefficient of the variable “fertiliser” is found to be 0.99 implying that if use of the quantity of fertiliser is increased by one percent, the output will be increased by 0.99 percent. However, a one percent increase in the quantity of land would decrease output by 7.35 percent, other things remaining the same. Though the negative elasticity of land is not in accordance with the expectation, given the nature of conditions required for cultivation of summer rice in the state this is not surprising. As outlined above, the cultivation of the crop is taken up in the state during November to April when normally rainfall is very scanty. Thus, the cultivation of the crop is not possible at all without irrigation. Therefore, it is obvious that a mere increase in land keeping all other factors constant will not enhance output.

It is also clear from Table 8.6 that output has the highest positive responsiveness to capital followed by irrigation, labour and fertiliser. It is also found that all the individual input elasticities are elastic for capital, irrigation and labour. However, the input elasticity for fertiliser is inelastic as the value of the elasticity is less than one.

From the individual elasticities of the inputs, total output elasticity or the measure of returns to scale can be obtained by adding elasticities for every input. This value indicates the percentage by which output will increase if all factors are varied in the same proportion. Since the sum of individual input elasticity is 1.56 (which is greater than one), there exists increasing returns to scale in production. In other words, an increase in all inputs by one percent increases production of summer rice by more than one percent.

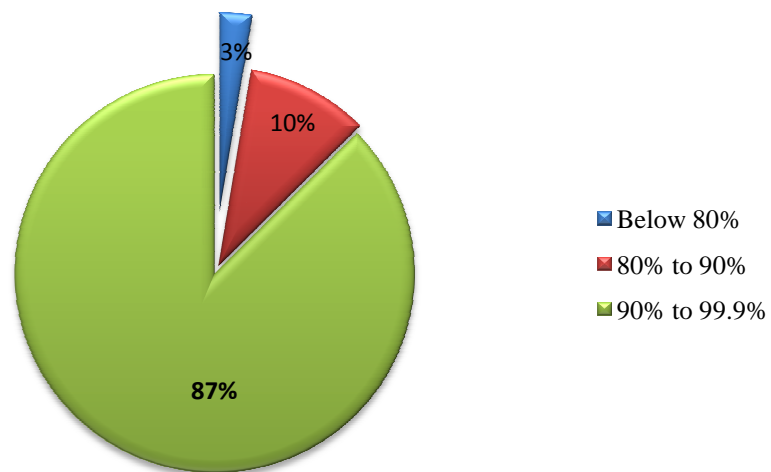
8.7.2 Technical Efficiency:

In the present study, output-oriented measure of technical efficiency is calculated where inefficiency is defined as the deviation of actual output from the maximum output obtainable from the bundle of inputs using the best available practice of technology. When the value of technical efficiency is one, the inefficiency is zero and the firm is able to achieve maximum output using the inputs. TE in this sense is also understood as

the ability of a firm to increase its output to the maximum possible level without corresponding increase in inputs (Khanna, 2006).

The estimated technical efficiency scores for each sample farm are converted into percent by multiplying them by 100. Technical efficiency score of each farm is also disaggregated by the status of the farmers in the groundwater market.

Figure 8.2
Distribution of Sample Farms According to their TE Scores



It is clear from Figure 8.2 that most of the farms (about 87 percent) exhibit technical efficiency scores of more than 90 percent. Only a 3 percent of the sample farms have exhibited technical efficiency scores below 80 percent.

Table 8.7 shows the descriptive statistics of the estimated technical efficiency scores for all the farmers combined together and across different categories of groundwater users.

Table 8.7
Technical Efficiency Scores of Farmers under Different Structures of Groundwater Markets

Descriptive statistics	All	Self-users	Self-user + sellers	Self-user+ sellers +buyers	Self-users+ buyers	Buyers
Mean	0.941	0.936	0.942	0.950	0.885	0.943
Std. Deviation	0.062	0.107	0.037	0.032	0.169	0.064
Minimum	0.514	0.514	0.805	0.846	0.633	0.547
Maximum	0.983	0.981	0.983	0.982	0.980	0.982
Total observation	191	18	76	14	04	79

Difference between means (t-test):

Self-users+sellers+buyers and Buyers : $t = 0.401$; $P > |t| = 0.690$

Self-users+sellers+buyers and Self-users : $t = 0.815$; $P > |t| = 0.006$

Self-users+sellers and Self-users+buyers : $t = 2.22$; $P > |t| = 0.029$

The minimum estimated output oriented technical efficiency score for all farmers' plots is 0.514 when the maximum is 0.983. The average technical efficiency score is 0.941 with the standard deviation 0.062. This implies that on the average, the output produced is 94 percent of the best practice frontier output. In other words, output on all plots of the different categories of groundwater users can be increased by 6 percent through an effective use of their input bundle given their present state of technology. It also suggests that, on an average, only 6 percent of summer rice production is lost because of technical inefficiency.

Technical efficiency scores are segregated in to different categories of groundwater users in order to find out difference in the achievement of technical efficiency by these Groups of farmers. It is clear from Table 8.7 that there is no remarkable difference in the average TE scores achieved on the plots of "only buyers" and "only self-users+sellers". Average TE score on plots of these two categories of groundwater users is found to be 0.94 which is same with the average TE scores of all farms combined together. This finding is a little deviation from results of other studies on water market where the researchers have found buyers' plots to be technically less efficient than that of "self-user+sellers" (Khanna, 2006; Manjunatha, 2011a, 2011b). Though the average TE scores for these two categories of farmers are same, a noticeable difference is found

in the minimum TE scores. While the minimum TE scores on buyers' plots are found to be 0.547 the same is 0.805 on self-user-cum-sellers' plots. That the buyers' plots are equally technically efficient cannot be accepted at least in case of a few buyers who have recorded a very minimum TE scores compared to the "self-user+sellers".

Table 8.7 also indicates that on the average, plots owned and operated by the "self-user+sellers+buyers" have recorded the highest TE scores (0.982) among all groundwater users. The fact that plots operated by the "self-user+sellers+buyers" are technically more efficient than those plots of "self-users" implies that farmers participating in the groundwater market are more efficient in input use than those who have not participated. However, in order to assess whether the difference in average value of technical efficiency scores (between "self-users+sellers+buyers" and "buyers" as well as between "self-users+sellers+buyers" and "self-users+sellers") are statistically significant, the t-test is carried out. Since the distribution of the individual technical efficiency scores for "self-users+sellers+buyers", "self-user+sellers" and buyers follow the normal distribution (suggested by Kolmogorov-Smirnov test⁹), t-statistic is used. The calculated t-statistic presented in Table 8.8, suggests that between "self-users+sellers+buyers" and "sellers" the difference in mean technical efficiency scores is found to be statistically significant. But the computed t-statistic for "self-users+sellers+buyers" and "buyers" is not statistically significant. As the t-statistic is not significant, it can be concluded that the estimates of TE scores are not significantly different between either of the two categories of groundwater users. However, t-statistics for the mean technical efficiency scores obtained by "self-users+sellers" and "self-users+buyers" is statistically significant. It indicates that those self-users who are not water sellers but buy water on some other plots, are technically less efficient than those of self-users who sell water after meeting their own requirement.

The technical efficiency scores of the sample farmers are also categorised according to the size of their operational holdings. The descriptive statistics of technical efficiency scores for farmers under different categories according to the size of their operational holdings are shown in Table 8.8.

Table 8.8**Technical Efficiency Scores of Farmers According to the Size of their Operational Holdings under Different Structures of Groundwater Markets**

Descriptive statistics	All	Marginal	Small	Semi-medium	Medium
Mean	0.941	0.949	0.947	0.927	0.866
Std. Deviation	0.062	0.038	0.045	0.098	0.116
Minimum	0.514	0.774	0.725	0.514	0.633
Maximum	0.983	0.983	0.982	0.980	0.957
Total observation	191	82	64	39	06
<u>Difference between means (t-test):</u>					
Marginal and small	: t =0.157; P> t = 0.880				
Marginal and semi-medium:	: t = 1.550; P> t = 0.120				
Marginal and semi-medium+medium	: t = -2.160; P> t = 0.032				
Small and semi-medium	: t = 1.301; P> t = 0.190				
Small and Semi-medium+medium	: t = 1.870; P> t = 0.054				

It is evident from Table 8.8 that the average TE scores on both marginal and small plots are higher than the average technical efficiency scores of semi-medium and medium plots. It indicates that input use is relatively more effective on small and marginal plots than the medium plots. A t-test has been performed between marginal and small plots to assess whether the difference in technical efficiency scores are statistically significant. The test statistics is insignificant indicating that that estimated technical efficiency scores are not significantly different between the two categories at the mean levels. Similarly, the t-test conducted between marginal and semi-medium plots is also not significant implying that that estimated TE scores are not significantly different between the two categories of plots at the mean levels. However, t-tests performed between technical efficiency scores on marginal and semi-medium and medium plots (combined) as well as small and semi-medium and medium plots (combined) are significant at five percent level. This indicates that marginal and small plots are technically more efficient than the medium or semi-medium plots. This is probably due to the fact that on relatively smaller plots, the farmers can have better control on the input combination; hence, the farming is more effective.

The technical efficiency scores of the different categories of groundwater users can also be used to estimate potential gain in output from the inputs used, using the following formula:

$$Potential\ yield = \frac{100}{TE * Actual\ Yield}$$

The estimates of potential yield for the sample farmers and the maximum yield¹⁰ possible from the given input bundles are presented in table 8.9.

Table 8.9
Potential and Maximum Yield of Summer Rice on Plots of the Sample Farmers (per hectare)

Items	All		Self-users		Self-user and sellers		Self-user +sellers +buyers		Self-users + buyers		Buyers	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Potential yield per hectare (in quintal)	5.38	6.21	3.29	4.56	4.11	4.67	2.29	4.21	.81	.68	7.85	7.35
Maximum yield per hectare (in quintal)	73.56	13.39	73.53	16.32	72.33	12.65	71.35	11.08	71.33	23.98	75.27	13.30
Percent of potential yield to maximum yield	6.03	7.02	4.35	5.04	5.35	5.40	3.10	5.23	1.07	0.73	9.77	8.08

It is clear from Table 8.9 that on average the maximum output on farms' plot is 73.56 quintal per hectare. Among all five categories of groundwater users, on the average maximum output accrues to buyers' plots which is 75.27 quintals per hectare. On the average, the output on self-users' plots can be increased by about 4.35 percent, which on plots owned and operated by the "self-user+sellers" can potentially be increased by about 5.35 percent. While "self-users+sellers+buyers" could increase output potentially, on the average, by about 3.20 percent, "self-users+buyers" can do the same by about 1.07 percent and finally the buyers can potentially increase output by 9.77 percent. Thus, on the average, the greatest potential output gain accrues to the buyers of groundwater which is calculated as 7.85 quintal per hectare. The average potential output gain is 6.03 percent or 5.38 quintals per hectare when all farms are combined together.

8.7.3 Determinants of Inefficiency:

The maximum likelihood estimates of the inefficiency models are also jointly presented in Table 8.5. However, the estimates of the coefficients of inefficiency model are reproduced here in Table 8.10. While the first hypothesis test of the inefficiency model presented in section 8.6 of this chapter signifies presence of inefficiency, the second hypothesis test indicates presence of technical inefficiency. The third hypothesis test shows presence of farm specific factors in influencing the inefficiency. The fourth hypothesis test suggests significant role of the joint effects of the factors included in the model though some of them may not be significant individually. Following is a discussion on the determinants of technical inefficiency.

It is to be noted here that the dependent variable in the inefficiency model is technical inefficiency as opposed to technical efficiency. Hence, a negative sign for a coefficient in the technical inefficiency model indicates a decline in technical inefficiency. On the other hand, a positive sign of a coefficient indicates a rise in technical inefficiency.

Table 8.10
Maximum-likelihood Estimates of the Parameters of Translog Stochastic Frontier and Inefficiency Model

	Parameters	Translog	
		Coefficient	SE
Inefficiency Model			
Constant	δ_1	-1.252**	(0.545)
Age	δ_2	0.015**	(0.005)
Education	δ_3	0.071**	(0.026)
Off-farm income	δ_4	-0.114***	(0.068)
Access to credit	δ_5	0.218***	(0.131)
Extension	δ_6	-0.030**	(0.014)
Organic manure	δ_7	-0.212**	(0.118)
Micronutrient	δ_8	-0.001	(0.077)
σ^2		0.047*	(0.009)
Γ		0.547*	(0.113)
Log likelihood function		79.92	
Mean technical efficiency (in percent)		94.10	

*, ** and *** represent significance at 1 percent, 5 percent and 10 percent level.

The results presented in Table 8.10 reveal that the availability of off-farm income in the farm household, farmers' contact with extension services and application of organic manure are significant factors of inefficiency model and the sign of the coefficients of

these variables are found to be negative. The negative signs of the coefficients of the variables indicate contribution of these variables to reduction of technical inefficiency. This implies that these are the significant factors increasing technical efficiency of the sample farmers.

As evident from Table 8.10, the coefficient of the variable “off-farm family income” is found to be highly significant and bears a negative sign. This implies that a farm household with subsidiary sources of income can attain relatively more technical efficiency in the production of summer rice than the others. This may be due to several reasons: *firstly*, a farm household with stable subsidiary sources of income may enjoy capacity to invest on tubewell enabling farmers to enjoy more control on timely application of groundwater during the crucial period of crop growth. *Secondly*, availability of off-farm income of the farm household also enables the farmer to buy other inputs like fertilisers, pesticides and weedicides. It also helps the farm household to mechanise cultivation, which also increases production.

Interaction with the extension services given by the government is found to be a significant factor in attaining technical efficiency by the sample farmers. The coefficient of the variable is found to be negative implying that when a farmer receives extension services, it helps the farmer to reduce technical inefficiency in production. Better extension services help the farmers in adoption and use of better farming practices, timely and adequate application of groundwater which makes the farming technically more efficient.

The use of organic manure is found to have significant and positive impact on the attainment of technical efficiency by the sample farmers. Since, organic manure is naturally very conducive to the soil quality which is an age-old practice of farming adopted by the farmers; its use can be enhanced in order to attain maximum possible output along with other input mix.

The variables like education, age and access to credit are also significant but the signs of their coefficients are positive. Thus, these variables are negatively related with technical efficiency. Though the results of the variables taking negative sign seem quite possible, the contradiction with variables such as education, age, access to credit taking positive signs needs further investigation.

The negative relationship of the variable “education” with technical efficiency contradicts the results of Khanna’s (2006) study on technical efficiency of sugarcane producers under water market in Uttar Pradesh. Khanna found that education helped farmers to reduce technical inefficiency. However, in the present study, as majority of the farmers are illiterate and have attained education up to 5th standard only, there is possibility that education of the farmer is not contributing towards reduction in technical inefficiency of the farmer.

Like education, variable like age of a farmer and his access to credit is found to be exerting a negative impact on technical efficiency of the sample farmers in the present study. This is generally believed that when a farmer becomes older the farmer enjoys greater experience in farming and becomes more skillful. However, if the farmer is constrained by financial incapability, the modern agricultural inputs could not be used. This may deter technical efficiency of the farms. Similarly, though access to credit from formal sources enables the farmer to purchase pumpset and other modern tools of agriculture, if credit is not directly utilised for the procurement of these items, mere access will never help. Therefore, the study identifies necessity of enquiring use of credit taken for agricultural purposes. Though there is an increasing tendency of the sample farmers to use micronutrient in the production of summer rice, this is not found to be a significant determinant of technical efficiency.

8.8 Summing Up:

In this chapter, the stochastic frontier production technique is used to estimate the technical efficiency of the farms under different structures of groundwater markets. The analysis has also provided an explanation for the variation in the farm specific technical efficiency among the sample farmers. The estimates of the stochastic translog production function incorporating the inefficiency effect, have shown that about 55 percent of the random variation in summer rice production is explained by the presence of technical inefficiency (TE). While looking at the TE scores attained by the farmers under different structures of the market, it has been found that average technical efficiency scores on both buyers and sellers’ plots are similar (their average TE score is 0.942). This finding is not similar to the findings of the previous studies on water market such as Manjunatha et al. (2011a, 2011b) and Khanna (2006). While, Manjunatha et al. (2011a) have found buyers’ plots to be technically more efficient than

sellers' plots, Khanna (2006) has found owner's plots to be technically more efficient than that of the buyers' plots. In the present study, on the average, owners of tubewell who have participated in the market as "self-users+sellers+buyers", have attained higher average technical efficiency score than those owners of tubewells who have not participated in groundwater transaction. It suggests that market has induced enhancement of technical efficiency of the farmers who have participated in groundwater transaction. The average TE score of owners-cum-buyers (0.885) is found to be lower than that of owners-cum-sellers (0.936). It implies that the owners of tubewells who have taken up cultivation of summer rice on other fragmented plots with purchased water are technically less efficient than those who sell water. Thus, in the present study, though there are differences in input use and the market is reported to be unreliable by a majority of the sample buyers, there is no remarkable difference in the average TE scores between the buyers and sellers. The almost equal average technical efficiency score attained by both buyers and sellers indicates that they have been able to make better or appropriate use of given inputs in the cultivation of summer rice.

It has also been found that on the average, small and marginal plots have recorded higher technical efficiency score than the semi-medium and medium plots. This indicates that input use in smaller plots is technically more efficient compared to the larger one. Though technical efficiency scores, on the average, on both buyers' and sellers' plots are similar, it is found that there is further scope for increasing output on buyers' plots. It is due to the fact that a few buyers have recorded the lowest TE score among all sample farmers. The availability of off-farm income in the farm household, better contact with the extension agencies and the use of organic manure are the significant factors determining technical efficiency of the sample farms.

Notes:

1. Suppose, with two inputs labour and water a firm produces Q with the production function specified as: $Q = f(L, W)$

Where, Q represents output, L amount of labour and W amount of water. Q represents the maximum amount of output that can be produced using alternative combination of L and W . Q is also known as Total Physical Product (TPP).

The Marginal physical product of an input is the additional output that can be produced by employing one more unit of that input while holding all other inputs constant. That is,

For example, MPP water, $MP_w = \frac{\partial Q}{\partial w}$

The Average Physical Product is a measure of efficiency. The APP depends on the level of inputs employed. $AP_w = \frac{Q}{w}$

The elasticity of supply of an input measures how an output responds to changes in inputs. This is obtained by dividing the MPP by the APP.

Given the output price, Marginal Value Product (MVP) = MPP* price of output

The profit function thus, be generated as $\pi = TVP - TVC$

Applying the first order condition we get a change in profit with respect to change in input.

In our example, $\frac{\Delta\pi}{\Delta w} = MVP - MVC = 0$

For a profit maximizing firm, MVP should be equal to unit of input (MVC). Therefore, to determine if all inputs are used at efficient (optimal level) the MVP is equated to the unit factor price.

2. Tadesse and Krishnamaorthy (2007) noted this aspect of importance of efficiency measurement as efficiency is an important factor for productivity growth.

3. When stochastic frontier production function is established with no explicit distribution for the efficiency component, the frontier could be estimated using corrected ordinary least squares (COLS). However if an explicit distribution is assumed such as exponential, half-normal or gamma distribution, then the frontier is estimated by maximum likelihood estimates (MLE) (Brave-Ureta et al. 1993). Green (1980) makes use of the specific distribution term and found MLE efficient than COLS.

4. The critical value of χ^2 for 15 degrees of freedom is 24.384 (Kade and Pam 1986)

5. Test statistics of Breusch-Pagan heteroscedasticity test $\chi^2 = 0.39; P > |\chi^2| = 0.531$.

Test statistics for White test $\chi^2 = 116.77; P > |\chi^2| = 0.752$

6. $\gamma = 0$ when $\sigma_u^2 \rightarrow 0$ or $\sigma_v^2 \rightarrow 1$

7. Assuming right hand part of equation 7.10 to be equal to U,

$$\Rightarrow Y = e^U$$

Now applying chain rule of differentiation,

$$\frac{\partial Y}{\partial land} = \frac{\partial Y}{\partial U} \times \frac{\partial U}{\partial land}$$

Now, taking partial differentiation of U with respect to land, we obtain:

$$\frac{\partial U}{\partial land} = \frac{(\beta_1 + 2\beta_6 + \beta_{11} + \beta_{12} + \beta_{13} + \beta_{14})}{land}$$

$$\frac{\partial Y}{\partial U} = e^U = Y$$

Thus,

$$\frac{\partial Y}{\partial land} = \frac{\partial Y}{\partial U} \times \frac{\partial U}{\partial land} = Y \cdot \frac{(\theta_1 + 2\theta_6 + \theta_{11} + \theta_{12} + \theta_{13} + \theta_{14})}{land}$$

⁸ Negative elasticities associated with frontier models indicate that input use of the respective variable should not be associated with best practice output production (Battese and Broca, 1997).

⁹ If $F_b(X)$ and $F_s(X)$ stand for the empirical cumulative frequency distributions of individual technical efficiency scores of sellers and “self-user+sellers+buyers”, the Kolmogorov-Smirnov’s test statics $D = \max|F_b(X) - F_s(X)| = 0.2970$ with the corresponding p value 0.206, which is not significant. Similarly, if $F_b(X)$ and $F_s(X)$ stand for the empirical cumulative frequency distributions of individual technical efficiency scores of buyers and “self-user+sellers+buyers”, the Kolmogorov-Smirnov’s test statics $D = \max|F_b(X) - F_s(X)| = 0.3716$ with the corresponding p value 0.056, which is not significant at five percent level of significance. These show that the distribution of individual technical efficiency scores of buyers, “self-user+sellers” and “buyers+self-users+sellers” follow a normal distribution.

¹⁰ Maximum yield = Actual yield + Potential yield.



CHAPTER NINE

SUMMARY OF FINDINGS, CONCLUSION AND POLICY SUGGESTIONS

The present study is motivated by the debate and discussion on the issues of groundwater markets, which are mostly region specific. Broadly, the study may be viewed as a research contribution to the effort to address the issues of groundwater markets in the state of Assam. However, before drawing the final conclusion and elicit policy implications, it may be worthwhile to recapitulate the principal findings of the study. A brief summary of these findings is presented in the following section.

9.1 Principal Findings:

9.1.1 Development of Groundwater Based Irrigation in Assam:

- Of all the irrigation schemes, minor irrigation accounts for the maximum irrigation potential created (about 83 percent of the total potential) in the state. Irrigation development under minor irrigation schemes has been on rise since 1980s.
- The rapid growth of groundwater based minor irrigation schemes has outpaced the surface flow and surface lift schemes under MI schemes.
- There is dominance of Shallow Tubewells (STWs) over Dug Wells and Deep Tubewells among the groundwater structures. STWs constitute more than 90 percent of total groundwater structures in the state.
- The small and marginal farmers are the largest beneficiaries of STW based irrigation development of the state.
- Subsidy given by the government under its different schemes, for installation of STWs has largely enabled the small and marginal farmers to own tubewells.
- Majority of the pumpsets (98 percent) in the state are diesel operated. The rate of diffusion of electric pumpsets is rather low. Given the erratic and insufficient supply of electricity, diesel operated pumpsets are considered to be more reliable by the farmers.

- The proliferation of private tubewell irrigation system has stimulated ground water transaction among farmers resulting in the emergence of water markets in some pockets of the state.

9.1.2 The Nature, Structure and Functioning of Groundwater Markets:

- The sample farmers, owning a tubewell, extract water considering groundwater as their private property and engage in water selling. No tubewell owner is constrained by any government regulation. There are no such rules set by the government which might influence functioning of the market in the study area. There is also no such social restriction against entering the market. The owners of tubewells sell water without any written contract agreement with the buyers. Thus, the groundwater market in the study area is informal similar to water market found in other Asian countries.
- Due to limited availability of conveyance facilities, water transaction in the study area is limited to the sample farm households who live in the same village and work in the same crop field or live in different villages but work in same crop field. Thus, the groundwater market observed in the study area is a localised institution supporting Shah's (1993) dictum that 'localised nature of groundwater markets is almost universal'.
- Six alternative forms of market arrangement have been noticed in the study facilitating farmer's access to groundwater. They are categorised as "self-users" (those farmers who own tubewell and use it for own cultivation), "self-users+sellers" (those owners of tubewell who use it for own cultivation and sell water), "self-users+sellers+buyers" (those owners of tubewells who use it for own cultivation, sell water and also purchase water on their fragmented plots), "buyers" (those farmers who do not own tubewells but purchase water from other owners of tubewells), "self-users+buyers" (those owners of tubewells who use it for own cultivation and also buy water from others) and finally, "owner+sellers" (those farmers who own tubewells to sell water).
- The emergence of category of "owners+sellers" indicates that the farmers without own cultivable land are also able to tap the benefits of water selling as an additional source of income. This is a new dimension of groundwater markets not reported in

major part of the literature on water markets except Shah (1993). This also suggests that water market has provided incentive to a few farmers to take groundwater pumping as a gainful economic opportunity. Moreover, it indicates that the market is not residual to all the buyers.

- Majority of the buyers are found to be marginal (56.82 percent) and small farmers (41.54 percent). Altogether they constitute about 98.36 percent of the total sample farms under different categories of farm holdings. Compared to this, buyers in the semi-medium category are only 5.13 percent. The size-wise analysis explicitly shows that when the farm size increases, the number of buyers decreases. It has been found that with increase in farm size, the number of self-users have increased.
- About 65.98 percent of sample sellers are marginal and small farmers out of which about 34.02 percent are in marginal category and 31.96 percent belong to small farm category. About 28.86 percent are in semi-medium category and a very small 5.15 percent are in medium farm category. Thus, the majority of the water sellers are concentrated in the categories of small and marginal farmers. This contradicts one of the established theories of groundwater markets that water sellers are always the large and wealthy farmers.
- The number of sellers is found to have decreased with increase in the farm size. It is in contrast to an established theory of water markets that when farm size increases, the number of water sellers increases. The finding of the study confirms that when farm size increases the number of buyer decreases but the reverse is not always true for the sellers.
- The average size of operational holding of a sample buyer is found to be 0.9 hectares. But the average size of operational holding of a sample seller in all categories except for “owners+sellers” remains higher than the average size of the total operational holding (1.35 hectare) for all the participants in the market. This implies that the farm size of the water sellers has remained relatively larger than the buyers.
- The total sample tubewell owners (119) have irrigated a gross area of 308.66 hectares (average per WED owner is 2.59 hectares) including both own use and water sale. The total number of pumpsets owned and operated by the sample

tubewell owners is 185 (both diesel and electric tubewells). Thus, the average irrigated area served by a pumpset is 1.67 hectares. Out of this total irrigated area for the cultivation of summer rice, each owner of WED irrigates a gross area of 144.65 hectares (average 1.22 hectares per WED owner) of own cultivable land for the production of summer rice. Out of the total WED owners, about 81.52 percent are engaged in water selling. These WED owners have sold water to a total area of 164.18 hectares (average area sold per WED is 1.38 hectares) for the cultivation of summer rice. The total irrigation potential (measured in terms of area irrigated by a WED) sold (53.19 percent) is higher than use of the same for own purpose (46.85 percent). This 164.18 hectares of land is distributed among 354 number of buyers each buyer owning 0.49 hectares of land on the average.

- While looking at the size of the groundwater market from the buyers' point of view, it has been found that a total of 97 sample buyers have irrigated a gross area of 85.68 hectares of cultivable land for the production of summer rice, each buyer irrigating on an average, 0.88 hectares of land. Out of the total sample buyers, about 74.23 percent have purchased water from one seller. While about 18.56 percent have purchased water from two sellers and the rest 7.22 percent have purchased from three sellers. The buyers' choice for multiple sellers is primarily due to fragmentation of their cultivable plots.
- The size of the market from seller's point of view indicates that total sale volume (measured in terms of area served by a tubewell) is greater than that of the self-operated area. There is also a presence of multiple sellers against a buyer. This indicates that major share of the area served by tubewells in the study area, is likely to be owned and operated by the buyers of water.
- The water contract is found to be linked with land tenure system. Water buyers cultivate in self-owned plots or leased-in plots (from water sellers in a large number of cases) or in both the plots. Though there is no input sharing other than water, the provision of water is not free. A few tenant-buyers are required to render some other services to the water sellers. There are no formal and informal restrictions on the choice of contract between buyers and sellers. Contracts have

been found to be flexible to some extent when the buyers and sellers are relatives of each other.

- Transaction in the market is found to have taken place in both cash and kind. Between the two, kind payment is found to be the dominant mode of water transaction. The in kind charges are of two types, viz. fixed charge and output sharing. The output sharing has taken two forms, viz. output-sharing with or without sharing of cost.
- While about 74.22 percent of the sample farmers have made purely kind based transaction, about 23.20 percent have made the transaction in cash. About 5.55 percent of the sample farmers have preferred both cash and in kind payment.
- Under in kind payment, about 66.49 percent of the total sample farmers have paid a fixed charge and 7.73 percent of the total sample farmers have made the payment on output sharing basis. Under a fixed charge contract, water buyers pay a fixed amount of the produce for a season for a specified irrigation acreage generally one *bigha* (equivalent to 0.133 hectare) after the harvest of that crop. Under the output sharing in kind payment, the buyers pay for the water for the season by providing a certain portion of their produce after the harvest of that crop.
- The water charge collected is based on area approach where the amount of water charged is based on the area of land irrigated. This is unlike the case in majority of the empirical studies on water market which have reported hourly rate to be more prominent.
- Under the prevalent system in groundwater market in the study area, the buyers are required to pay for the diesel when they buy water from diesel operated pumpsets. But in case of water purchased from an electric pumpset, buyers are not required to pay the electricity bills. This affects the price charged for water. Under cash payment, the average price charged per hectare of land for all sample farmers participating in the groundwater market is ₹ 3, 361.50 if water is bought from the diesel powered tubewells and ₹ 5, 695.87 if water is bought from the electric tubewells. Rates of water charge based on kind (with fixed charge) is 7.41 quintals per hectare of land, minimum and maximum being the 5.97 quintals/hectare and 11.93 quintals/hectare respectively when water is bought from a diesel tubewell.

The prevalent rates under output sharing system are found to vary from one-third to two-thirds of the total produce.

- The prevalent water charge is found to be uniform at the village level indicating that the market is more competitive. The incidence of price variation which is found to be present in a few villages is due to location of the villages in relatively high land.
- It has been found that about 31.95 percent of the total sample buyers have leased in land from the sample water sellers and about 42.27 percent of the total sample water sellers have leased out land to the water buyers. Whereas, 64.79 percent of the total cases of tenancy have taken the form of fixed charge, about 32.40 percent are based on output sharing. The existing average water charge with tenancy is about 14.94 quintals/hectare (8.96 quintals/hectare for land and 5.98 quintals/hectare for water). The study notes no differential treatment by the water sellers between tenant-buyers and other buyers unlike the case in some of the literature on water markets.
- It has been found that about 25.57 percent of the sample sellers have given concession on water charge to their buyers. While about 56 percent of them have given concession to their brothers, the rest 44 percent have given concession to their relatives. It has been found that the transaction between water buying and water selling farm households is also influenced by presence of personal relationship between the two. The extent of this price concession in the study area varies from 1.49 quintals per hectare (10 percent of the actual water charge) to 5.97 quintals per hectare (23.3 percent of the actual water charge). In majority of the cases, a concession of 2.98 quintals per hectare is given. While the brothers of the water sellers have enjoyed concession of either 5.97 quintals per hectare from the sellers or full concession (conditioned by serious illness), the relatives of the water sellers have enjoyed a concession of 2.98 quintals per hectare.
- About 5.67 percent of the water sellers have reported that there remains an overdue in the payment of water charge. The relatives of the water sellers are the highest defaulters (44.45 percent) followed by any buyer (37.04 percent) and the tenants of the water sellers (9.26 percent). Of the total defaulters, around 38.88 percent are

permanent defaulters out of which 57.14 percent have been found to be the relatives of the water sellers. Thus, brothers and relatives of the sample sellers are the defaulters in payment of water charge.

- About 35.05 percent of the sample buyers have provided some other services to the water sellers. Majority of the sample water buyers (about 67.64 percent) are required to provide any sort of services demanded by the water sellers. Different types of services rendered by the buyers include protecting and operating the pumpsets in the crop field, transporting the pumpset to the field and any sort of services demanded by the water sellers. Interestingly buyers are not paid for these services.
- There is preferential treatment of the buyers by the sellers. Usually, siblings and close relatives are provided with high preference in providing water by the sellers. This indicates that the market practices are not purely based on conventional economic model which is endogenous to market system. Instead, the water sellers exercise some monopoly power though not reflected in the market prices for groundwater, through some other means which are exogenous to the market system.
- About 45.83 percent of the existing water sellers, who are engaged in water selling for more than 20 years, have reported that there is decline in number of buyers over the years.
- Majority of the water sellers have cited that labour shortage, steep rise in input prices, particularly chemical fertiliser and inadequate procurement price of the crop are among the factors that have compelled most of the buyers to give up cultivation of summer rice resulting in net reduction in market transaction.
- About 43.75 percent of the sample water sellers who have faced the problem of non-availability of sufficient water have reported failure of the pumpsets in delivering required quantity of water. Owing to this, a few farmers have expressed their apprehension that unfettered penetration of pumpsets may cause conflict over the use of groundwater.
- No such great deal of difference between buyers and sellers in the number of application of groundwater in the crop field has been noticed. While the average

number of irrigation on sellers' plots has been found to be 14 numbers, the same on buyers' plots has been found to be 11 numbers during the whole season.

- A sample water seller is found to have multiple number of buyers which in the study is found to be 3.6 against a seller. For distribution of water among the buyers, a rotation method is practised. However, there is no concrete rotational period. In some sample villages, while a 3 day rotation period has been followed, in some cases farmers have to wait for more than 7 days depending on the number of buyers against a seller.

9.1.3 Tubewell Characteristics and Operation of Groundwater Markets:

- About 78.79 percent of the pumpsets are about 10 years old. Only 19.45 percent of the pumpset have been procured in the last five years. However, some operational pumpsets were bought 20 years back. Interestingly those pumpsets procured 20 years back are still used in water selling activities. This indicates that the groundwater transaction in the sample villages has been in vogue for more than two decades.
- In the field, 119 owners of tubewells are found to own 185 tubewells indicating about 1.55 number of tubewells per owner. Out of these sample owners, about 81.51 percent are engaged in water selling. The total number of present buyers who have purchased water from these sellers are 354. This indicates that one tubewell serves 2.46 number of buyers.
- In view of high operational cost of a diesel operated tubewell, as high as 78.15 percent of tubewell owners have expressed their preference for electricity operated tubewells over diesel operated tubewells. However, due to erratic electricity supply, the sample farmers have a general tendency to rely on diesel operated pumpsets to ensure assured irrigation. The higher and fluctuating diesel price has also forced many sample farmers to drastically reduce their cultivable area under summer rice which is mainly based on groundwater irrigation. There have been cases of shifting of some buyers to electricity operated tubewells.

- About 88.65 percent of the sample sellers are found to have sold water to the buyers whose plots are adjacent to the sellers' plots. A small section of the sellers (about 11.35 percent) are found to sell water to the buyers whose plots are located a little away from the source of irrigation. In such a situation, the buyers have been found to be using both earthen channels and polyvinyl chloride (PVC) plastic pipes for conveying irrigation water to the field. However, provision of earthen water channels is available when buyers are tenants of the water sellers. In the rest of the cases, buyers have been found to use PVC pipe. Buyers normally prefer plastic pipe as it helps in avoiding conveyance loss. If the plots of the second seller is available in between the seller's plots and the farmer's plots, conveyance facilities through the second seller's plots is normally not permitted.

9.1.4 Production System across Different Participants of Groundwater Markets:

- Since availability of irrigation water is ensured, the use of HYV seeds is universal in the study area.
- Among all the activities, the use of machine is the highest in ploughing. While about 59.49 percent of the buyers have used tractor or power tiller for ploughing the crop field, about 68.75 percent of the "self-users+sellers" have used the same in ploughing. This is followed by spraying where about 40.18 percent of the "self-users+sellers" and about 43.03 percent of the buyers have used the powered spraying.
- Fertiliser consumption (N+P+K) is found to be 162.95 kg per hectare for all the sample farmers. There are marginal differences in the rate of fertiliser consumption between the water buyers and owners-cum-sellers. While the average rate of consumption of fertiliser is 161.82 kg per hectare for the buyers, the same is 163.78 kg per hectare for the sellers.
- The Gross Cropped Area (GCA) for all sample farm units (191) is found to be 180.69 hectares. The total output from the GCA is found to be 12,447.58 quintals. Thus, the average yield of summer rice for all farm units is found to be 68.89 quintal/hectare. While the farms adopting old varieties of HYV seeds have recorded average yield of 68.18 quintal/per hectare, the farms adopting new HYV seeds have recorded relatively much higher yield of 81.45 quintal/per hectare.

- There is variation in yield of the crop among different categories of participants of groundwater market. This variation is found to be in the range of 66.44 quintal/per hectare to 75.27 quintal/per hectare across different categories of farmers. While the yield is found to be almost same among “self-users” and “self-users+sellers” at 70.29 quintal/ per hectare and 70.57 quintal/per hectare respectively, “self-users+sellers+buyers” have registered the highest yield of 75.27 quintal/per hectare. While “self-users+buyers” have realised 68.78 quintal/per hectare, the “buyers” have registered the lowest of 66.44 quintal/per hectare among all the categories of participants of groundwater users.
- Only about 23.70 percent and about 5.60 percent of the sample farmers have good and very good contact with the extension agencies respectively. This indicates that about one fourth of the total farmers have benefited from the extension services of the government. About 47.50 percent of the total sample farmers are not even aware of the personnel of extension agencies for their respective area. The rest 23.70 percent of the sample farmers, although knew the personnel, have not received any direct benefit from the extension service. Thus, on the whole, the extension services in the study area are not good.
- Compared to the sample “buyers”, the “self-user+sellers” have better contact with the extension agencies. About 40.78 percent of the sample “self-users+sellers” have good or very good contact with the extension agencies and are also benefited from the service. Compared to this, only about 19 percent of the sample buyers have good and very good contact with the extension agencies.

9.1.5 Determinants of Water Buying Decision:

- Own farm size has been found to have negative and significant influence on the probability of farmer’s decision to purchase water. This implies that increase in own farm size reduces the probability of buying water of a farmer.
- For a tenant farmer, the probability of buying water is high as “tenancy” as a factor influencing water buying decision is found to be significant and positive. Tenancy being a significant determinant of water purchase decision indicates presence of a

stronger interlinkage between operation of water market and the existing land tenure system.

- A farmer's probability of buying water increases when the distance of his plots from the nearest source of irrigation/tubewell increases. The elasticity coefficient of this variable is estimated to be (-) 0.35. This implies that when distance of buyer's plots from the nearest source of tubewell increase by one percent, the probability of purchasing water decreases by 35 percent, *ceteris paribus*.
- The "age" of the head of the farm household as a factor influencing the probability of water purchase has been found to be significant and negative. When experience increases the farmer may find it better to own a tubewell than buying water as water purchase is also beset with the question of reliability of groundwater markets.
- Personal relationship between the buyers and sellers as a factor influencing water purchase decision of a farmer has been found to be significant but negative. It indicates that the probability of a farmer's decision to buy water decreases when he has personal relationship with the water sellers.
- The coefficient of the variable "farmers' contact with the extension agencies" is found to be negative and highly significant. It indicates that when a farmer has better contact with extension agencies, it reduces the probability of a farmer's water buying decision.

9.1.6 Determinants of Tubewell Ownership:

- Own farm size of a farmer has been found to be a significant factor determining his probability of tubewell ownership. The positive coefficient of the variable implies that a farmer's probability to own a tubewell increases when his own farm size increases.
- When area under the largest compact plot is large, the probability to own a pumpset rather than resorting to water purchase is also high.
- Farmers' access to institutional credit is found to be a significant factor influencing the probability of tubewell ownership. The positive coefficient of the variable

indicates that when a farmer has an access to formal credit his probability of owning a tubewell increases.

- The impact of level of education of a farmer on his decision to own a pumpset is found to be positive and significant. This implies that with education the farmer may see the benefits of ownership of tubewells in terms of cost and reliability in providing water in the field as and when required.
- The coefficient of the variable “AGE” is also found to be significant and positive. The elasticity coefficient of the variable implies that when age of the farmer increases by one percent, the probability of tubewell ownership, *ceteris paribus*, increases by 54 percent.
- The fragmentation of land holding as a factor influencing tubewell ownerships has been found to be significant and negative. It indicates that when the number of fragmented plots increases, the probability of farmers’ tubewell ownership decreases.
- The relationship between a farmer’s decision to own a tubewell and his contact with the extension agencies is found to be positive and significant. This indicates that when a farmer receives better extension services in the form of information on farming practices, the farmer is more likely to own a tubewell.

9.1.7 Determinants of Water Selling Decision:

- The role of excess capacity of a tubewell as a factor on the probability of water selling decision of owners has been found to be significant and positive. This indicates that when an owner has excess capacity of his tubewells, the probability of water selling by the farmer increases.
- The depth of boring as a factor influencing the probability of water selling decision of a farmer is found to be significant and positive indicating that when the depth of boring increases the probability of water selling of the owners of tubewells enhances.

- It has been found that the owners of diesel operated tubewells have a higher probability of selling water than the owners of electricity operated tubewells and owners of both diesel operated and electricity operated tubewells. This is confirmed by the negative and significant coefficient of the variable “electricity operated tubewells”.
- The coefficient of the variable “presence of conveyance facilities” is significant and bears a positive sign. This indicates that availability of conveyance facilities increases the probability of selling water by an owner of tubewell.
- “Caste” as a variable affecting the probability of water selling is found to be significant and negative. The negative coefficient of the variable indicates that unlike findings of most of the studies on water markets, the probability of selling water of an owner of tubewell in the state is not found to be biased towards farmers belonging to general category. In fact, farmers belonging to other categories have a higher probability of selling water than those under the general category.

9.1.8 Reliability of Groundwater Markets and its Determinants:

- While nearly 50 percent of the water sellers have found sufficient availability of water, about 49.48 percent have reported that water is not sufficiently available to meet their requirements for own use and sale.
- Groundwater has not been found to be sufficiently available by the water sellers during peak demand periods mainly due to relative scarcity of groundwater arising from simultaneous drafting in a few locations, mechanical breakdown and due to electricity shortages in case of owners of electricity operated pumpsets.
- While looking at the issue of reliability of groundwater markets from the buyers’ point of view, it has been found that as many as 60 sample buyers (about 62 percent of the sample buyers) have reported that the water market is unreliable. Another 36.67 percent of the sample buyers have found the market unreliable as their respective sellers could not supply water due to presence of multiple buyers, their inability to buy diesel and for some other unspecified reasons. About 36.67 percent have been unable to buy diesel to run the pumpsets at the time of requirement. While about 8.33 percent have reported frequent pumpset failure,

about 1.67 percent have attributed it to inadequate supply of electricity for running the respective sellers' pumpsets. About 16.67 percent have not cited any specific reason for non-availability of water for them.

- Among the buyers who have found the market reliable, as high as 62.16 percent have personal relationship with their existing sellers and about 29.70 percent are tenants of the water sellers.
- The quantity of groundwater purchase (measured in terms of buyer's cultivated area) as a factor influencing probability of reliability of the market is found to be highly significant and negative. This implies that when the demand for water purchase is high there is greater likelihood to have inadequate supply of water.
- The probability of reliability of the groundwater market to the buyers has been found to be higher with diesel operated tubewells than the electricity operated tubewells. The elasticity coefficient of the same variable also indicates that *ceteris paribus*, when water is bought from the diesel operated tubewells, the probability of reliability decreases by 102 percent.
- "Tenancy" as a variable is statistically significant and its coefficient is found to be positive. This implies that if a farmer is a tenant of the water seller, his probability of getting a reliable water market is higher than others. This also indicates that the groundwater market is strongly intertwined with the existing land tenure system making the practice relatively less reliable for non-tenant buyers.
- Education of the head of the farm household has been found to have a significant and negative influence on the likelihood of groundwater markets becoming reliable for the buyers. Thus, though education may enhance managerial capacity of the farmers-cum-buyers in terms of input use, etc., but higher educational qualification may not guarantee reliability of the groundwater market in provisioning of adequate quantity of groundwater for the buyers.

9.1.8 Technical Efficiency and Groundwater Markets:

- The estimated value of the variance (γ) parameter which is a measure of the level of technical inefficiency effects in the stochastic frontier model is found to be 0.55.

This implies that 55 percent of the random variation in summer rice production of the sample farmers is explained by presence of inefficiency. The presence of inefficiency implies that through a redistribution of the current input bundle, farmers can improve their production of summer rice.

- More than 87 percent of the total sample farms have exhibited technical efficiency scores of more than 90 percent. Only a 3 percent of the sample farms have shown technical efficiency scores below 80 percent.
- The minimum estimated output oriented technical efficiency score for all farmers' plots is 0.514 when the maximum is 0.983. The average technical efficiency score is found to be 0.941 with a standard deviation of 0.062. This implies that, on the average, the output produced is 94 percent of the best practice frontier output. In other words, output on all plots of the different categories of groundwater users can be increased by 6 percent through an effective use of their input bundle given their present state of technology.
- The average TE score on the plots of both "buyers" and "self-users+sellers" is found to be 0.94 which is same with the average TE score of all farms combined together. However, the minimum TE score on buyers' plots is found to be 0.547 while the same is 0.805 on self-user+sellers' plots. On the average, plots owned and operated by the "self-user+sellers+buyers" have recorded the highest TE score (0.952) among all groundwater users.
- The fact that plots owned and operated by the "self-user+sellers+buyers" are technically more efficient than those plots owned and operated by the "self-users" implies that farmers participating in groundwater markets are technically more efficient in input use than the non-participants.
- On the average, the maximum output on farmers' plot is 73.56 quintal per hectare. Among all five categories of groundwater users, on the average, maximum output accrues to buyers' plot which is found to be 75.27 quintals per hectare. On the average, output on self-users' plot can be increased by 4.35 percent. While the "self-user+sellers" can potentially increase output by 5.35 percent, the "self-users+sellers+buyers" could increase output potentially by 3.20 percent, "self-users+buyers" can do the same by 1.07 percent and finally the buyers can potentially increase output by 9.77 percent.

- The determinants of inefficiency show that availability of off-farm income sources, better contact with extension agencies and use of organic manure in cultivation result in reduction of technical inefficiency. However, education and age of the head of the farm household and the use of micronutrient in cultivation have been found to be contributing to inefficiency.

9.2 Conclusion:

It has been clear from the logit regression analyses that own farm size, farmers' access to institutional credit, availability of off-farm income, fragmentation of land holdings, farmers' contact with the extension agencies, excess capacity of a tubewell, education and age of head of the farm household are some of the significant determinants of tubewell ownership and water buying and selling decisions of a farmer. The logit regression analysis of the determinants of tubewell ownership and water buying decision has shown that own farm size is a significant factor influencing the probability of farmers' decision to own tubewells and buy water. In case of tubewell ownership, the positive relationship between the two indicates that when own farm size increases, the probability of a farmer's decision to own tubewells increases. Regarding water buying decision, the coefficient of the variable is found to be negative implying that the farmer's probability to buy water decreases when own farm size increases. However, the role of this factor on the probability of water selling decision of a farmer has been found to be insignificant. Therefore, the hypothesis that "emergence of water market is influenced by own farm size of farmers" gets partially accepted.

Regarding reliability of groundwater markets, it has been found that about 48.75 percent of the sample owners-cum-sellers have found unavailability of adequate water due to pumpset/boring failure, relative scarcity of groundwater and inadequate supply of electricity. From the buyers' point of view, as high as 62 percent of the buyers have found the market unreliable for them. The results of the logit regression analysis have shown that quantity of groundwater purchase (measured in terms of buyer's cultivated plots), tenancy and types of fuel/power are significant determinants of reliability of the groundwater market. Thus, the discussion on reliability of the market in the study area points towards inadequate supply of groundwater to a majority of sample buyers. Thus, the evidence from the field study does not provide general support to the hypothesis that

“groundwater markets ensure reliability of water supply”. Hence, the hypothesis gets rejected.

The results of the stochastic translog production function and inefficiency model indicate presence of technical inefficiency (TE) with a difference of up to 55 percent between the observed and best practice output. While looking at the TE scores of farmers under different structures of the market, it has been found that both buyers and sellers’ plots have exhibited similar average technical efficiency score of 0.942. Since average TE scores on plots owned and operated by only buyers and only “self-users+sellers” are found to be almost same, groundwater market can be viewed enhancing TE on purchased plots despite the market being unreliable for some of the buyers. The owners of tubewells who have participated in the market as “self-users+sellers+buyers”, have attained higher average technical efficiency score than those of non-participants. Since plots owned and operated by the “self-users+sellers+buyers” ranked the highest in terms technical efficiency score compared to the plots owned and operated by the “self-users”, the hypothesis that “groundwater market enhances technical efficiency of farms” gets accepted.

9.3 Policy Suggestions:

The main policy suggestions emanating from the findings of the study are summed up in the following points:

1. Though groundwater based irrigation has been promoted in the state for furthering agricultural development as the state is endowed with abundant replenishable groundwater reserves, it has been found that the cost of pumping is high due to the dependence on diesel operated tubewells. This has resulted in decline in the absolute number of groundwater buyers over the years. Although electricity operated tubewells entail lower cost per unit of water supplied, absence of electricity connections (in a few places) and low voltage, irregular supply with several power cuts (where electricity connections are available) are some of the major obstacles felt by both water sellers and water buyers. Thus, the investments in rural electrification are desirable so that the farmers can tap the resource lying plenty beneath their land. In the similar line, it can be mentioned that fragmentation of land holdings has been found to have negative impact on

ownership decision of tubewell. Therefore, in order to enable marginal and small farmers to own a tubewell, consolidation of land holdings and joint ownership of tubewell may be promoted.

2. Though groundwater markets have facilitated access to groundwater among small and marginal farmers, the study finds that the market is sometimes less reliable to some of the buyers. This suggests that individual ownership is always the best arrangement to gain control over the use of the most crucial input, water. Since small farmers may not be able to buy the pumpset as it involves relatively large capital outlay, subsidy at the time of procurement of the pumpsets may be given to the small and marginal farmers. Further, as farmers' access to formal credit is found to be one of the important determinants of tubewell ownership, availability of credit facility will also help the small farmers in this regard.
3. Since, lower levels of education of the sample farmers has contributed to technical inefficiency (as the average years of schooling attended by the sample farmers are very much lower), emphasis should be given on training to make the farmers more efficient in use of inputs. The training should also focus on management of irrigation so that the farmers can make efficient and sustainable use of the resource. The extension services on such practices by the government should be strengthened.
4. It has been found that groundwater market has widened access to groundwater among small and marginal farmers. Additionally, a few tubewell owners (5.88 percent) have been found to be engaged in selling groundwater primarily to make profit. Ground water markets, in this sense, can also be viewed as an institution facilitating diversification of income sources to a few farmers. However, pumping of groundwater is associated with social cost as groundwater is a common pool resource. Though groundwater reserve is abundant in the state, a majority of the owners have reported relative scarcity of it, especially at the time of simultaneous drafting. In view of the fact that market induced-over pumping has already caused depletion of groundwater reserves in water scarce regions of India, this suggests that some intervention for regulating market activities through some formal rules (at the state or community levels) is desirable so that (i) equal

access is granted to everyone as everybody has a stake over the common pool resource and (ii) over pumping can be controlled.

9.4 Limitations of the Study and the Scope for Future Research:

Some of the limitations of the study as observed by the researcher are mentioned below:

1. In the present study, sample farm households are drawn mainly from low lying Central Brahmaputra Valley Zone (CBVZ) of the state where the groundwater market is found to be prevalent in the cultivation of summer rice. Since the crop is also cultivated (using STWs) in other parts of the state, presence of such markets in those areas cannot be ruled out. Therefore, by drawing sample from those parts, the study could have been made more illustrative and effective in drawing a comparative picture on the nature and functioning of water markets in the state. However, such comparative analysis could not be carried out as the present study is confined to the districts of CBVZ only. This can be considered as the limitation of the study and an area of research in future.
2. The study has estimated technical efficiency of farms which cultivate summer rice using groundwater as a critical input. However, for a comprehensive understanding of efficiency in water use, it is also important to look at the allocative efficiency of the farms. The present study, could not attempt estimation of allocative efficiency of the farms as in the market water is not traded as per se. In the course of the study, it has become an overwhelming task to collect information on exact quantity of water discharged by a pumpset making the calculation of marginal value product of water extremely difficult. Failing to look at the allocative efficiency is one of the limitations of the study. However, this can be taken up in the future study of water markets in the region.
3. The functioning of water market is nested with so many other institution (government, households, property over land, social norms in the village, informal rules and regulation prevailing in the village, political institutions at the village level, other markets in the village and outside, etc. Therefore, an analysis focusing on market and its related institutions deems essential to understand the entire institutional dynamism of the groundwater market in the study area. Thus, there is scope to study the interaction of different institutions (formal or informal) with the prevailing water

market using the sophisticated tools of institutional economics. Failure to cover this within the ambit of the present study, may be considered as one of the limitations of the study



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Appendix- 4.1: Questionnaire Administered in the Field to Collect Primary Data

‘Institution for the Use of Groundwater in Assam: A Study of Groundwater Markets with Special Emphasis on Structure, Determinants, Reliability and Efficiency’

“A study undertaken for Ph.D. in the Department of Humanities and Social Sciences, Indian Institute of Technology Guwahati, Guwahati 39, Assam, India, Phone: 91-(361)-2582600, Fax: + 91-(361)-2582599”

Date of Record:

1. Name of the district:
2. Name of the development block:
3. Name of the agricultural circle:
4. Name of the village:
5. Caste: [General-1, OBC (CL)-2, OBC (NCL)-3, SC-4 and ST(P)-5, ST (H)-6]
6. Religion: [Hinduism-1, Islam-2, Christianity-3 and Others-4(specify)]
7. Community: [Assamese -1, Bengali -2, Nepali -3, Tribal-4 and Others-5(specify)]
8. If tribal, specify the tribe:
9. Details of family background:

Sl. No.	Relation to the head	Gender	Marital status	Family type	Age (in years)	Years of schooling	Occupation
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							

[Gender: 1-Male, 2-Female; Education: 1- Class I, 2-Class II.... 10 - Class X and so on; Family Type: 1- Nuclear, 2-Joint, 3-Unitary and Extended, Name the occupation as reported; Marital Status: Married-1, Unmarried-2, record the case as reported if married but husband died, wife dead, remarried, etc.]

10. Household characteristics and related socio-economic information

Sl. No.	Information	Response
1	Type of house (1 -Kutchha ,2- Semi Pucca, 3- Pucca)	
2	Availability of electricity connection (Yes -1, No 2)	
3	Types of electricity connection (Domestic-1, Commercial-2)	
4	Type of ration card (No-0, Antodaya-1, BPL-2, APL-3, Others-4(others specify))	
5	Distance from pucca road	
6	Distance from the market place/weekly hat	
7	Availability of cold storage in the village? (Yes -1, No 2)	
8	Distance of cold storage from home	
9	Distance from the nearest commercial bank branch	
10	Availability of retail outlet for fertilisers, pesticides etc. in the village (Yes-1 No-2)	
11	Availability of diesel in the village for irrigation (Yes-1, No-2)	

11. Details of assets/consumer durables held by the household

SL No	Type of asset/consumer durable	(Yes-1/No-2) /Number	Year of purchase/opening
1	Radio		
2	TV (Color/Black and White)		
3	Computer (Whether internet facility?)		
4	Bicycle		
5	Motor cycle		
6	Carrier van		
7	Thela		
8	Rikshaw cycle		
9	Bullock cart		
10	Insurance policies	Life Insurance (amount)	
		Kisan Credit Card (amount)	
11	Savings (Weekly/Monthly)	Commercial Banks (amount)	
		Post office (amount)	
		Others (specify)	
12			
13			
14			
15			
16			

12. Size of land holdings and utilisation

Sl. No.	Items		Area
1	Homestead/courtyard		
2	Details of cultivable land		
2.a	Owned		
2.b	Leased in	Fixed rent/produce	
		SC with cost sharing	
		SC without cost sharing	
		Mortgage	
		Any other (specify)	
		Total	
2.c	Leased out	Fixed rent/produce	
		SC with cost sharing	
		SC without cost sharing	
		Mortgage	
		Any other (specify)	
		Total	
2.d	Cultivated area held		
2.e	Total land holding		
2.f	Area under largest compact plot		
2.g	No. of plots in which cultivated area is fragmented		
	Number	Whether boring? (Yes-1, No-2)	
3	Fallow		
4	Forest, orchard, pond, grazing land, fishery		
5	Any other (specify)		
Note: SC: Sharing Cropping			

13.6 Types of operation:

[Individually by the household – 1, Jointly – 2 and Mixed (both 1 and 2) – 3]

13. Details of machine used in cultivation in the reference year

Operation	Machinery use	Response code
Ploughing(tillage)	[Animal drawn indigenous plough-1, Animal drawn mould board plough-2, tractor-3, power tiller-4]	
Leveling/Harrowing	[Animal drawn indigenous leveler-1, Disc harrow -2]	
Puddling	[Indigenous plough-1, Disc harrow/animal drawn helical blade puddler-2, PT drawn rotavator-3,Tractor drawn rotavator-4]	
Bund making	[Manual spade-1, Machine-2]	
Sowing	[Manual-1, Sowing machine2]	
Seedling	[Manual-1, Seed drill (machine)-2]	
Transplanting	[Manual placement-1, Manual transplanter-2, Self-propelled paddy transplanter-3]	
Fertiliser use	[Manual-1, Leveler-2]	
Weeding	[Hand picking-1, Khurpi-2, Japanese wet land paddy weeder-3]	
Spraying	[Manual knapsack-1, Sprayer machine-2, Sprayer and duster-3]	
Harvesting	[Manual cutting by sickle-1, Power tiller driven reaper harvester/tractor drawn reaper harvester-2, Self-propelled reaper harvester-3]	
Transporting	[Shoulder carriage and cart-1, Bullock cart-2, Power tiller trolley-3, Tractor trolley -4]	
Threshing	Bullock treading-1, Power thresher-2]	

14. Ownership of capital goods used in cultivation:

Items	Owned (number)	Year of purchase	Purchase price (in Rs.)	Sources of finance (amount in Rs.)			
				1	2	3	4
Tractor							
Power tiller							
Bullock pair							
Sprayer							
Harvester							
Others (specify)							

Notes: 1-Self-finance, 2-Borrowing from money lenders, 3-Borrowing from non-institutional sources, 4-Borrowing from institutional sources
*Record life time of the capital goods

15. Details of crop grown

S.N.	Crop Groups/Crops→								
1	Variety (T-1, HYV-2)*								
2	Area								
3	Area irrigated								
4. Fertiliser	Urea	Amount							
	SSP	Amount							
	MOP	Amount							
	DAP	Amount							
	Organic M	Amount							
5.	Micronutrient	Amount							
6.	Seeds	Amount							
7.	Pesticide	Amount							
8.	Weedicides	Amount							
9	Others	Amount							
10	Tilling (No.)/Bigha								
11	Details of labour used								
a. Tilli ng	Family	Mandays							
	Hired	Mandays							
b. So wing	Family	Mandays							
	Hired	Mandays							
c. Har vestin g	Family	Mandays							
	Hired	Mandays							
d. We eding	Family	Mandays							
	Hired	Mandays							
12	Yield per bigha								
13	Production								
14	Amount sold								
15	Mode of sale*								
16	Price								
17	Last year production								
Notes: Variety: Traditional-1, High Yielding Variety-2; Mode of sale: Collected by traders-1, Delivered to traders-2, Village huts-3, Procurement agency-4, Sold to hauler mills/processing units-5, Any other-6 (specify), * if HYV name of the variety									

16. Crop-wise current expenditure on capital goods used:

Items↓	Crops (Specify) →							
Tractor	Rent (if hired)							
	Fuel (Cost)							
Power Tiller	Rent (if hired)							
	Fuel (Cost)							
Bullock	Rent (if hired)							
Sprayer	Days used							
	Rent (if hired)							
Harvester	Rent (if hired)							
Irrigation Assets	Rent if hired							
Others	Period of use							
	Rent (if hired)							

17. Expenditure on cultivation (excluding capital expenditure)

Heads/Items	Amount of expenditure (in Rs.)	Sources of finance (amount in Rs.)			
		1	2	3	4
Seed					
Fertiliser					
Pesticides					
Payment for wage labour					
Interest on loan					
Any other (specify)					
Total					

Notes: 1-Self-finance, 2-Borrowing from money lenders, 3-Borrowing from non-institutional sources, 4-Borrowing from institutional sources

18. Whether irrigation water is used for cultivation? (Yes-1, No- 2)

i. If yes, what is the source of irrigation? (STW-1, LLP-2)

ii. Whether irrigation system is: (Owned-1, Shared-2 and Hired-3)

iii. If owned, year of installation of the pumpset:

iv. Distance from the neighbouring source of irrigation:

v. Depth of the boring:

vi. Capacity of the system:

vii. Diameter of the boring:

viii. Types of fuel/power: (*Diesel-1, Electricity-2*)

a. If diesel, cost of diesel: (price/liter):

b. Amount of diesel required:

Items	Amount (in liter)	Cost (amount in Rs.)
Hour wise/Per hour		
Area wise/Per bigha		

ix. If electricity, unit cost of electricity?

x. Total units used (per hour/whole season)

xi. Total bill paid (amount in Rs.)

xii. Supply of electricity in the peak season of cultivation:

(*Regular-1, Erratic-2, Not available-3*)

xiii. Do you want to convert it into electric connection? (*Yes-1, No-2*)

19. Capital and recurring expenditure on installation and the operation of the irrigation system (in the reference year):

Heads/Items	Total amount (in Rs)	Cash (in Rs)	Subsidy (in Rs)	Mode of finance			
				1	2	3	4
Cost of the machine *							
Cost of equipments							
Cost of installation (includes labour)							
Cost of Fuel							
Repair and maintenance cost							
Other (Specify)							

Notes: *Record Capacity of the machine; Mode of finance: 1-Self-finance, 2-Borrowing from money lenders, 3-Borrowing from non-institutional sources, 4-Borrowing from institutional sources

20. Utilisation of the irrigation system:

i. Volume of utilisation:

Total volume used for own use	Total amount sold	Amount unutilised

ii. If unutilised, reasons for non-utilisation of the irrigation system:

iii. Do you use your pumpset for other purposes? (*Yes-1, No-2*)

iv. If yes, mention the other uses:

21. If water is sold, details of transaction:

i. For what purpose water is sold? (*Agriculture-1, Non-agriculture purpose-2*)

ii. Volume of water sold:

Gallon	Hours	Area

iii. Mode of transaction of water sold:

(*Cash-1, Kind (with fixed charge) - 2, Kind (with output sharing)-3*)

iv. If cash, amount per hour/area wise:

v. In cash transaction, what is the amount per hour/area when diesel is purchased by the buyer?

:

vi. If output sharing, the share of the water seller:

vii. If the mode of transaction is output sharing, is cost sharing practised? (*Yes-1, No-2*)

viii. If yes, share of the cost borne by the seller?

ix. Does there remain a balance in water transaction? (*Yes-1, No-2*)

x. If yes, are these balances repaid in time? (*Yes-1, No-2*)

xi. If no, which category of buyers is the most frequent defaulter?
[Relatives/Kinship-1, Tenants-2, Others -3 (specify)]

xii. Do you sell water only to the neighbouring farmers? (Yes-1, No-2)

xiii. If no, how is water conveyed to the distant cultivable plot by the farmers?

xiv. What is the present number of buyers?

xv. Is the number of buyer decreasing over the years? (Yes-1, No-2)

xvi. If yes, what do you think is the most probable reason for this?

xvii. Do you have any personal relationship with the existing buyers? (Yes-1, No-2)

xviii. If yes specify the relationship:

[(Kinship-1, Same caste-2, Same religion-3, others -4 (specify))]

xix. Do you charge different price from different buyers? (Yes-1, No-2)

xx. If yes, reasons for this:

xxi. Is any buyer your tenant? (Yes-1, No-2)

xxii. If yes, forms of land tenancy? (Fixed charge-1, Output sharing-2)

xxiii. If crop/output sharing, share of output going to land owner:

xxiv. Do you provide irrigation free to your tenant? (Yes-1, No-2)

xxv. Have you experienced any problem in your pump-set in extracting water?
(Yes-1, No-2)

xxvi. If yes, nature of the problem:

xxvii. Have you had to increase the depth of the boring? (*Yes-1, No-2*)

xxviii. Are you planning to install another boring? (*Yes -1, No-2*)

xxix. If yes, reasons for this:

xxx. Do you have any shallow tube well which is not in use for the last three or five years?

(*Yes-1, No-2*)

xxxi. If yes, whether (*Temporarily -1 or Permanently-2*)

xxxii. If permanently, is this due to?

[*Salinity of water-1, Dried up-2, Destroyed-3, Others - 4 (specify)*]

22. Have you resorted to purchase of water for irrigation (*Yes-1, No-2*)

i. If yes, details of transaction:

Volume of water bought			Water charge	
Gallon	Hours	Area	In Cash	In Kind

ii. What do you prefer to be the means for water charge? (*Cash-1, Kind-2*)

iii. If kind, types of water charge: [*Fixed charge-1, Output Sharing-2*]

iv. If output sharing, nature of output sharing:

v. Is output/crop sharing linked with other input sharing? (*Yes-1, No-2*)

vi. If yes, mention nature of the sharing:

vii. Total number of irrigation? (per day/whole season)

Crop	Area cultivated	Area irrigated	Number of irrigation

viii. Do you buy water from one seller? (Yes-1, No-2)

ix. If no, why do you choose multiple sellers? [(Agricultural plots are scattered in different places-1, One seller cannot fulfill the demand-2, Any other-3 (specify)]

x. Have you leased-in land from your seller? (Yes-1, No-2)

xi. If yes, forms of land tenancy? [Fixed rent/produce-1, Output sharing-2, Mortgage-3, Any other-4 (specify)]

xii. If output sharing, is it (Output sharing with Cost sharing-1, Output sharing without cost sharing-2)?

xiii. Is your tenancy attached with fee provision for irrigation? (Yes-1, No-2)

xiv. What is method for distribution of water among buyers?

23. Whether number of purchase of irrigation water is adequate for irrigating field? (Yes-1, No-2)

24. If no, why do you think it is inadequate? (Sellers do not provide water in the peak seasons-1, Unable to purchase-2, Availability of fuel/power is inadequate-3, Water is not available-4)

25. Do you need to provide other services to the water sellers? (Yes-1, No-2)

26. If yes, mention these services:

27. Does the seller pay for these services? (*Yes-1, No-2*)

28. Have you ever refused to provide these services? (*Yes-1, No-2*)

29. If yes, what has happened after refusing it?

30. Have you started growing new crops since irrigation has become available? (*Yes-1, No-2*), if yes, if variety changed:

Name of the new variety	Variety it has replaced	Production/ bigha of the new crop	Improvement over the previous crop*

*Record production of previous crops

If crop replaced:

Name of the new crops	Crops it has replaced	Production/ bigha of the new crop (value in Rs.)	Improvement over the previous crop*(value in Rs.)

*Record production of previous crops

31. Extension Help:

i. Do you know the VLEW of your village? (*Yes-1, No-2*) (If no, then directly go to 'v')

ii. If yes, then when did you meet him last?

(Within last seven days-1, Within last 30 days-2, Over last 30 days-3, Cannot be remembered-4)

iii. Did you consult him on farming problems during the last agricultural season?

(Yes-1, No-2)

iv. Have you followed his advice and found them useful?

(Did not follow-1, Followed but found useless-2, Followed and found useful-3, No opinion-4)

v. Do you know the ADO of your area? (Yes-1, No-2)

vi. Did he visit your village in the last three months? (Yes-1, No-2)

vii. Comment on extension service (if received):

(Extremely dissatisfied-1, Somewhat dissatisfied-2, No opinion-3, Partially satisfied-4, Extremely satisfied-5)

32. Social capital of the farmers

i. Is there any FMCs (Field Management Committees) in the village? (Yes-1, No- 2)

ii. If yes, are you a member of the FMC? (Yes- 1, No- 2)

iii. What is the total number of members?

iv. How many times did the members meet in the last 6 months?

v. Have you attended any meeting in the last 6 months? (Yes-1, No-2)

vi. If no, what are the reasons for this?

vii. What was the last major decision taken in the meeting?

viii. What kind of role do you expect from the FMC in future?

ix. Are you a member of any one of the following farmer's organization?

x.

Sl No	Farmers' Association	(Yes -1)	(No- 2)
1	Water Users Association (WUA)		
2	Self-Help Groups (SHG)		
3	Any other non-political Association (Please Mention)		

xi. If there exists any WUA in the village, what is the role of it?

[Distribution of water-1, Collection of water charges-2, Advising farmers for cultivation-3, Conflict resolution-4, Others-5 (specify)]

33. Property Rights:

i. Whom do you think to be the owner of the groundwater?

(Private individual who has land-1, Community-2, State-3, No owner-3)

ii. Is there any restriction on the use of ground water? (Yes-1, No-2)

iii. If yes, what are these restrictions?

iv. Who puts these restrictions?

v. Do you need to take permission for installation of boring from the government?

(Yes-1, No-2)

vi. If yes, do you adhere to the norms stated? (Yes-1, No-2)

vii. If no, what are the reasons for this?

viii. Do you feel delivery of water from your shallow tube well has been disturbed due to operation/running of neighbouring wells? (Yes-1, No-2)

ix. If yes, when does it occur?

(During draught in summer season-1, During kharif season-2, At any time during the year-3)

x. Have you lodged any complaint to the owners of neighbouring wells? (Yes-1, No-2)

xi. Did he/you respond to you/him by not running the pump set at the same time?

(Yes-1, No-2)

xii. If no, have any conflict arisen among you over use of groundwater? (Yes-1, No-2)

xiii. If yes, how is the conflict resolved?

xiv. Whom do you think to be the owner of groundwater for better management?

[Individual/private-1, Community-2, State-3, Other (specify)]

34. Investigator's remark:



