Groundwater Sustainability : A Common Pool Resource Approach Towards its Management

THESIS

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Under the Supervision of
Prof. Sanatan Nayak

Submitted By
Pragya Sharma

DEPARTMENT OF ECONOMICS
School For Ambedkar Studies
Babasaheb Bhimrao Ambedkar University
(A Central University)
Vidhya Vihar, Raebareli Road Lucknow-226025 (U.P.), India

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I declare that thesis entitled "**Groundwater Sustainability: A Common Pool Resource Approach Towards its Management**" submitted to Babasaheb Bhimrao Ambedkar University, (A Central University), Lucknow for the award of Doctor of Philosophy in Economics. It is my original work and it has not previously been produced for any degree, diploma, certificate, fellowship or similar other titles anywhere.

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Pragya Sharma
(Enrolment No. 1019/15)
Department of Economics
Babasaheb Bhimrao Ambedkar University

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Supervisor

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(केन्द्रीय विश्वविद्यालय)
विद्या विहार, रायबरेली रोड, लखनऊ–226 025

BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY
(A Central University)
Vidya Vihar, Raebareli Road, Lucknow-226 025

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Dedicated to

All Individuals Who Value Environment

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Place: Lucknow **Pragya Sharma**
Date: (Enrolment No. 1019/15)

Preface

The basis for the study titled **"Groundwater Sustainability: A Common Pool Resource Approach Towards its Management"** stemmed from rising groundwater stress in India. Growing population, urbanisation, consumerism have lead to ever increasing demand for more of everything ranging from food to several other products/commodities. As environmental resources form the basis of almost all the production processes rising and unsustainable consumption patterns have lead to over-exploitation of natural assets viz. groundwater. This research work is entirely focused on groundwater as it is one of the most important water sources in the world. Moreover, groundwater, due to its common-pool resource nature and certain other socio-economic, behavioral, institutional, physical factors groundwater exhibit a tendency of depletion and degradation all across the globe. Continuous fall in water tables is resulting in several socio-economic and health implications eventually affecting overall economic development.

This study is an attempt to understand groundwater resources with reference to depletion, pollution and show the linkage between resource use and their impacts with particular reference to agriculture. Further, it tries to analyse the socio-economic factors that influence agriculture groundwater management and implications which groundwater stress has on economic and health conditions of farmers. In order to fulfill these objectives, apart from the secondary data, primary survey in Baghpat district has been conducted. This helped in understanding ground level issues and provides adequate solution.

Chapter I

Economic Development and Groundwater: Theoretical and Conceptual Framework

***"The 'environment' is where we live; and development is what we all do in attempting to improve our lot within that abode. The two are inseparable."*- Our Common Future, 1987**

1.0. Theoretical Background

Economic development is largely dependent on natural resources. Earlier, economic development was considered solely a result of physical and human capital but with deeper analysis of economic systems, special focus on environmental resources revealed that, there exists a third category of capital viz. natural capital which drives the development process. Studies and theories citing the importance of natural capital also highlighted that unsustainable growth patterns combined with various socio-economic factors would result in depletion and degradation of natural wealth. Such linkages between natural resources and economic development can be traced back to the time of classical economists viz. Malthus and Ricardo who stated the importance of natural resources in their respective theories. Thomas **Malthus (1798, p.4)** derived the conclusion that exponential growth pattern of population growth would result in inevitable decrease of food production per capita over time and decreasing living standards. Another classical economist **David Ricardo (1817, p.3)** paid attention to the relationship between population growth and land resources with particular reference to soil fertility. He focused on the changing quality of the soil as the main cause of the diminishing agricultural returns. Classicals believed that population development would eventually lead to stagnation and poverty due to finite amount of natural resources. The link between natural resources and economic development was further elaborated upon by the works of **Hotelling (1931, p.21)**. Focusing on the issue of exploitation of natural resources for material well being, **Simon Kuznets (1960,p.1)** gave EKC Hypothesis which stated that as per capita income increases environmental degradation rises initially but eventually declines. Later on **Hartwick (1977, p.291)**, understanding the role of natural capital in production activities and estimating the environmental crisis suggested investment in produced capital (buildings, roads, knowledge stocks, etc.) so as to offset declining stocks of non-renewable resources. During the classical time period not much attention was paid to the market activities and their impact on environment. However, there were discussions among scholars about people's behaviour towards natural resources since a long time. **Thucydides (431-401 BC)** noted that "people devote a very small fraction of time to consideration of a public object. Most of it is spend in prosecution of own objects. Meanwhile, each believes that their neglect would bring no harm and considers that taking care of public objects is somebody else's responsibility, and so, by this notion the common cause imperceptibly decays" (Ayotte and Smith, 2011,p.5). **Aristotle (350 BC, p.3)** remarked that goods held in common receive the least care. Such type of unowned or open-access resources tend to be over-exploited, degraded, and sometimes destroyed (Barnes, 2009, p.19). Aristotle argued that private ownership is better as it promotes virtues like prudence and responsibility: 'When everyone has a distinct interest, men will not complain of one another, and they will make more progress, because everyone will be attending to his own business'. This view was encouraged during the period 1954-1968, wherein several scholars developed the models emplacing such tragedies. **Gordon (1954) and Scott (1955)** argued that open access regime in fisheries lead ultimately to economic destruction of fish stocks (Gordon, 1954, p.123). According to them, individual fishers do not realize the costs they impose on other fishers and continue harvesting beyond optimal levels, thus overexploiting the resource. The behaviors suggested by Gordon, Scott and Hardin were also supported by **Mancur Olson** (**1965, p.2**). Olson stated that individuals may not cooperate with each other in protecting or using a resource at a sustainable rate unless "the size of group is quite small or some coercion or some special device to make individuals to act in their common interests". **Garrett Hardin's** (**1968, p.1243**) study in the same context gained worldwide attention. He in his classic paper "The Tragedy of the Commons" mentioned natural resources as commons i.e. shared by many individuals. In this context, "shared" means that each individual does not have a claim to any part of the resource, but rather, to the use of a portion of it for his/her own benefit. The tragedy is that, in the absence of regulation, each individual will have a tendency to exploit the commons to their own advantage, typically without limit. Under this state of affairs, the commons is depleted and eventually ruined. Considering this, most of the natural resources which are treated as common pool resource tend to be overused or exploited. Fisheries and forests are two common-pool resources that have been extensively studied while others on which several studies are being conducted include irrigation systems, groundwater basins, pastures, grazing systems, lakes, oceans, and the Earth's atmosphere etc. Scholars have assumed that all common-pool resources suffer from the same deficient incentive structure which leads to widespread 'free-riding'. This kind of individual's behaviour has been studied under game theory –Prisoner's Dilemma. The game puts individual rationality against collective rationality as each individual chooses his or her actions independently of one another (Schagler, 1998). Such conclusions highlighted the various aspects of common resources and the need for a management prescription which would prevent exploitation of these resources. Major works after this threw light on the need of resources for economic growth and unsustainable user behaviour. The arguments that the economic growth will be stopped due to the lack of resources, was immediately followed by the "energy crisis" in 1972 and 1974 which confirmed this hypothesis. Unregulated growth patterns and rise of various environmental crises was the genesis of the concept of sustainable development (Our Common Future, 1987). In economics terms, sustainable development has been considered as "Economic development today must ensure that future generations are left no worse off than present generations". Few economists put it as "per capita welfare should not be declining over time" (Pezzey, 1992,p.11). While it is generally accepted by most economists that economic development around the world is leading to the irreversible depletion of natural capital, there is widespread disagreement as to whether this necessarily implies that such development is inherently unsustainable (Maler, 1995, pp. 1-2). These two contrasting views are now generally referred to as weak sustainability versus strong sustainability. Modern day economists have also focused on the importance and need of natural resources for socio-economic development. **Herman Daly** triangle approach suggests natural resources to be the "ultimate means" for attaining "ultimate ends" i.e. economic development (Meadows, 1998, p.10). **Munasinghe**'s (2003, p. 8-10) sustainability triangle further substantiate it by showing the nexus between social, economic and ecological dimensions.

All the above mentioned studies suggest that even though the world is endowed with abundant natural resources but it does not mean that we can exploit them as per our desires. Natural resources are the basis of our survival and socio-economic development. Therefore, their scarcity and degradation would bear cost for the entire humankind.

1.1. Water and Economic Development: The Linkage

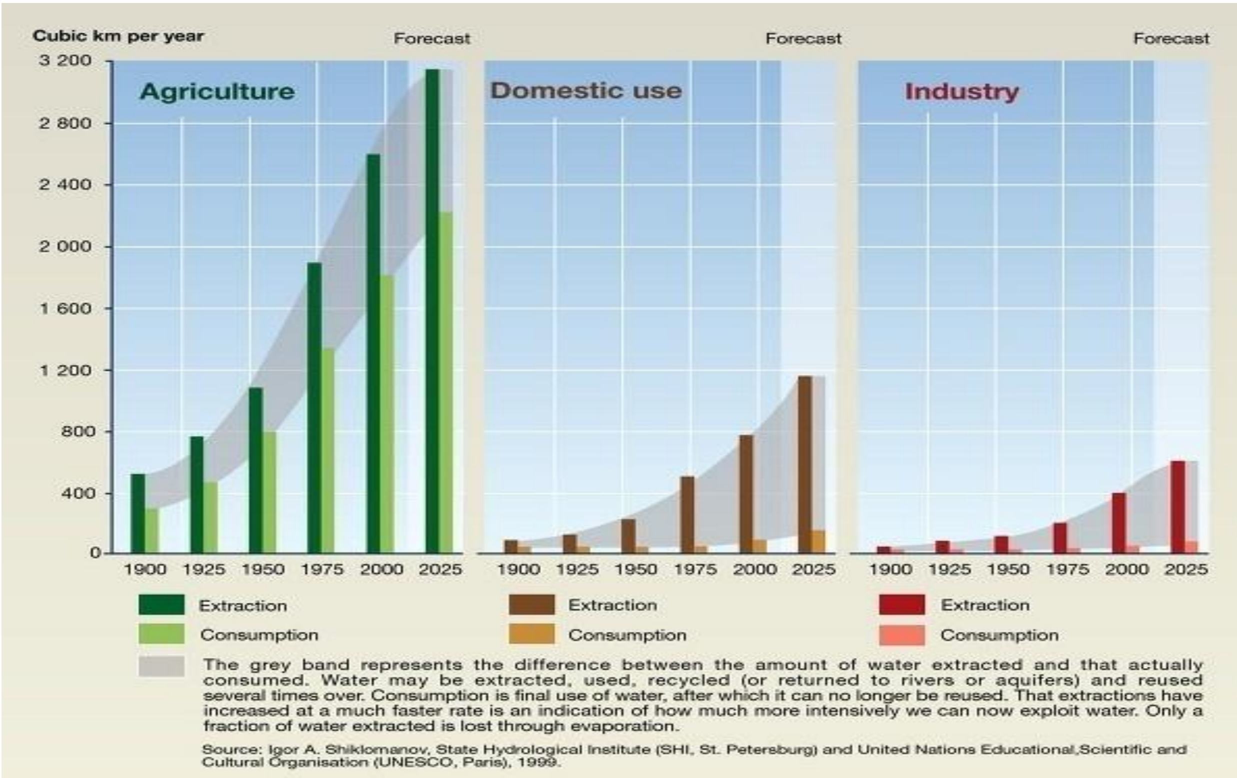
Water resources play an important role by virtue of their functions for human development, health, food security, industrial production, balance of the ecosystem and overall economic development. Water available for use is present in rivers, lakes or oceans and also lies underground which is termed as Groundwater. Although all the natural resources are necessary for fueling economic development the need for water is a basic one. "Water and economy are inextricably linked" (Sanctuary, 2007, p. 6-7). Diverse range of interactions exists between water and human activities and thus, socio-economic development processes seem to be closely related to the water resources. Water serves as a positive input for many activities: it serves essential biological functions, as a basic element of social and economic infrastructure, and as a natural amenity contributing to psychological welfare (UNESCO, 1987, p.1). Water can be substituted for but can rarely be replaced. Water is demanded for fulfilling basic human needs and for agriculture, industrial, energy production. In addition, transportation through waterways is essential for trade purposes. Water also holds recreational value and is necessary for maintaining environment sustainability (Berry, 2004, p.2). Summing it up, we may say that almost all components of economy are dependent heavily on water systems.

Exploring the linkage between economic growth and water resources, Barbier (2004, p.1) mentions that economic growth is negatively affected by the government's appropriation of output to supply water but positively influenced by the contribution of increased water use to capital productivity, leading to an inverted-U relationship between economic growth and the rate of water utilisation. Brown and Lall (2006, p.306-307) advance the hypothesis that the seasonal and inter-annual variability of rainfall is a significant and measurable factor in the economic development of nations thereby stating the importance of water. They reveal in their analysis of global datasets that a statistically significant relationship exists between greater rainfall variability and lower per capita GDP. The study further suggests poorest countries in this context are located in Africa. Therefore, the importance of securing water availability in these nations is necessary and it would increase every day in light of current population growth, economic development, and climate change projections.

1.2. Sector - Wise Water Usage

Focusing on sector wise use of water in economy, UNEP (2008, p.2) in virtual water graphics depict that agriculture is main consumer of water followed by households and industries respectively.

Fig.1: Global Sector Wise Water Usage



Source- United Nations Environment Programme (2008), Virtual Water Graphics.

As water resources are considered to be infinite they are being over-exploited. Over exploitation of water resources has resulted in extreme water scarcity and quality degradation in all parts of the world. With increased demand and rapid economic growth almost every natural resource is under stress but water stress seems to be the highest with several experts and academicians stating that the World War III would be over water. Agriculture is the main user of water resources accounting for almost 70 per cent of world's freshwater supply (Pacific Institute, 2015, p.4). Being the largest user it is considered to be main factor causing water scarcity and degradation. In addition to this, it is this sector which has felt the heat of water stress the most. Agricultural water use is under growing pressure as demand for water increase; competition among cities, farmers, and the environment grows; and as concerns grow over large-scale overdraft of groundwater and water contamination from agricultural runoff. New threats include the challenges of climate change, which is likely to alter both water availability and agricultural water demands.

According to FAO (2012) developing countries are particularly dependent on irrigation for impeding agriculture production. Food production has to be met with the demands of an expanding population and rising prosperity. Some of this demand could be satiated by increased productivity of rainfed agriculture, some by increased imports, but irrigated agriculture will remain a major contributor (Bruinsma, 2003, p.2).

Water used for irrigation comes from both *surface water* and *groundwater*. But, groundwater seems to take the lead in case of agriculture. Today, groundwater is estimated globally to provide 36 per cent of potable water, 42 per cent of water for irrigated agriculture and 24 per cent of direct industrial water supply (FAO, 2015, p.3).Agriculture tends to be, often by far, the most prolific exploiter and user of groundwater both in the developed world (chiefly for irrigated farming), and nearly all developing countries outside the humid inter-tropical zone: Saudi Arabia and the Libyan Arab Jamahiriya (90 per cent), India (89 per cent), Tunisia (85 per cent), South Africa (84 per cent), Spain (80 per cent), Bangladesh (77 per cent), Argentina (70 per cent), the United States of America (68 per cent), Australia (67 per cent), Mexico (64 per cent), Greece (58 per cent), Italy (57 per cent), China (54 per cent), etc. (UNESCO,2004).

1.3. Groundwater

Groundwater[1] represents one of the most important water sources in the world. Due to the highly variable nature of the climate, groundwater has become a popular alternative for irrigation and domestic water use across the globe. Reliance on groundwater resources is particularly strong when during dry season surface water levels are low or during wet season when flows are too disruptive to be conveniently tapped. In addition to being accessible, groundwater quality is generally excellent in most areas and presents a relatively safe source of drinking water as well as for other purposes water in rural and urban areas. The presence and availability of groundwater varies greatly with changes in topography, subsurface geology and the prevailing climate in the region. In some areas, groundwater exists in deep aquifers while in others the water is stored near the surface. The location of the aquifer also affects its recharge rate and its susceptibility to pollution and overuse.

[1] According to UN-International Groundwater Resource Assessment Centre, groundwater is contained in what are called 'aquifers'. An aquifer is a geological formation or part of it, consisting of permeable material capable to store/yield significant quantities of water.

The contribution from groundwater is vital, perhaps as many as two billion people depend directly upon aquifers for drinking water, and 40 per cent of the world's food is produced by irrigated agriculture that relies largely on groundwater (UNEP, 2003, p.6). Groundwater usage has been high due to several factors. Firstly, aquifers are very convenient sources of water as they are natural underground reservoirs and have enormous storage capacity. Secondly, many aquifers are able to offer natural protection from contamination so untreated groundwater is cleaner and safer than untreated surface water. Thirdly, groundwater is relatively easy and cheap to use. It can be brought on stream gradually with low capital investment. Lastly, it is a resource that is organisationally easy to develop, construct, operate and control as its supply can be managed by landowner.

Agriculture is the main user of groundwater in the world. Globally, irrigation accounts for more than 70 per cent of total water withdrawals and for more than 90 per cent of total consumptive water use (Siebert, 2010, p.1863). Studies mention that higher share of groundwater than that of surface water is due to the fact that groundwater is available on demand, at the point of use and requires little conveyance. Dhawan (1995, p.773) in his study have cited higher yields in groundwater irrigated areas. Yields are higher by one-third to one-half than those in areas irrigated from surface sources. The benefits of groundwater irrigation are numerous and they have been summed up by various authors (Shah, 1993; Moench, 1995). These include higher productivity and it's more equitable distribution among various classes of farmers, insurance against drought and stabilisation of agricultural production and enhanced employment generation. Data compiled from NSSO 54th Round data shows that a high percentage of households hire irrigation service in many states, which in turn reflects the extent of development of groundwater market in these states (Mukherjee, 2007, p.6).

With one-third of humanity totally dependent on groundwater for their daily needs and 98 per cent of the Planet Earth's accessible freshwater found in aquifers, there is a need to understand what would deliver sound governance of this natural resource in the face of its over exploitation and degradation. Over the last fifty years, groundwater withdrawal has more than quadrupled in volume and this trend is likely to continue (FAO, 2011, p.4). Considering agriculture sector of India, it is known that it has undergone massive changes after the initiation of Green revolution. Assessing the current trends, it is estimated that 60 per cent of groundwater sources will be in a critical state of degradation within the next twenty years (ibid). During last five decades, the number of dug wells increased from 3.86 million to 9.6 million, shallow tube wells from 3000 to 8.36 million and deep tube wells from negligible to 5.30 lakhs. Electric pump sets have increased from negligible to 14.81 million and Diesel pumps from 66,000 to about 6.34 million (Press Information Bureau, 2007). There has also been a steady increase in area irrigated by ground water. The increasing stress on ground water is further demonstrated by the fact that it has contributed nearly 80 per cent of the additional irrigated area created over the last two decades. Such extensive extraction of groundwater in some areas is leading to aquifer depletion. Sekhri (2012, pp. 2-3), in a research paper presents an overview of declining condition of groundwater in India. The most extensive decline in groundwater level is observed in north western India. In regions of Gujarat and Rajasthan, groundwater level fell by more than 16 meters over the period 1980-2010. In central Punjab and Haryana, the groundwater level declined between 12-16 meters. Punjab, Haryana, Rajasthan, Gujarat, Western Uttar Pradesh, and New Delhi also experienced significant declines between 8 to 12 meters.

1.4. Research Problem

Due to its common-pool resource nature, groundwater all over the world exhibits a tendency to deplete and getting polluted. Degradation of groundwater results from lack of recognition of rights and inappropriate arrangements for managing groundwater as a common-pool resource (Sarkar et.al, 2009, p.598). As of now, several of the world's major aquifers have reached a state of crisis, Ogallala aquifer[2] being a prominent example. Global groundwater extraction has increased fourfold during the last five decades. Withdrawal intensity varies widely with highest levels occurring over parts of China, India, Pakistan, Bangladesh, Iran, United States, Mexico and Europe. Hydrological studies state that under natural conditions, groundwater systems balance outflows with average inflows but intensive abstraction would eventually disrupt this balancing mechanism. This would ultimately lead to groundwater depletion and increased contamination (Konikow, 2011, p.317; Margat and Gun, 2013, p.131).Taking into account groundwater abstraction in India, Gurduno et.al (2011, p.2) state that India is largest user of groundwater in the world and so is the problem of over-abstraction of groundwater in both rural and urban settings. According to Wyrwoll (2012, p.16-17) between 1947 and 1967 India

[2] The High Plains aquifer, also known as the Ogallala aquifer, underlies about 112 million acres, or 175,000 square miles, in parts of eight states, including: Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Wyoming

underwent the Green Revolution, which bought a huge increase in agricultural production, making India one of the world's biggest exporters of grain. The availability of canal water led farmers to adopt highly profitable, but extremely water intensive crops, such as sugar cane. In addition, India achieved its goal of obtaining food security. Unfortunately, this huge surge in agriculture, required significant water resources for irrigation and accelerated the onset of present water shortages which has been satiated by groundwater. It is estimated that over 70 per cent of India's food grain production now comes from irrigated agriculture in which groundwater plays a dominant role (FAO, 2015, p.3). In this view, there exist a need to study the trends and current status of groundwater use and depletion over the time at macro and micro level. Another important aspect in this regard is developing the understanding of several factors behind rising groundwater stress which range from physical -cropping pattern, climate, irrigation method, etc.), economic -finance, insurance, difficult access to inputs, etc. (Birner et al. 2007, Fan et al. 2008, Gandhi and Namboodiri 2009, Kumar 2005, Mukherjee and Shah 2004, Scott and Shah 2004), social (consumer behavior, neighbors, responsibility of sponsoring, non-agricultural income, etc.) and institutional (ownership of water resources, lack of law enforcement etc.) (Narain, 1998; Singh, 1990; 1991; Azizi, 2001; Samian et.al, 2015). A major challenge in managing groundwater is its status as a common pool resource. It is a CPR with extremely high use value (FAO, 2015). The process of overexploitation of a common resource with open access results in "Tragedy of the Commons" (Hardin, 1968). As groundwater rights prevailing in India are closely related to land rights we need to focus on the same. They can be considered as a version of the English doctrine of absolute right wherein landowners have an absolute right to water under their land. When the land is sold, groundwater access rights gets passed on with the land. The volume of water extracted does not legally depend on the area of land owned and any landowner can abstract any volume of water (Narain, 1998; Singh, 1990; 1991. The Indian Easement Act, 1882 states that every landowner has the right to "collect and dispose" of all water under the land within his own limits, and all water on its surface that does not pass in a defined channel. Hence, by this Act, the owner of a piece of land does not "own" the groundwater under the land or surface water on the land; he only has the right to collect and use the water. However, it is customarily accepted across India that a well on a piece of land belongs to the owner of that land, and others have no right to extract water from the well or restrict the landowner's rights to use the water. Such legal framework often tends to create confusion over water rights and also leads to indiscriminate use of groundwater resources by implying that only the land owners own groundwater. Consequently, the landless that constitute more than 30 percent of the rural farm population are unable to enjoy private ownership of groundwater or other water rights (Mukherjee, 2007, p.12). This further leads to creation of water markets. Lack of water pricing and tax mechanisms also pose a challenge towards effective groundwater management. Central Groundwater Board mentions that till date no water rates as such are being charged from farmers. In addition, with respect to the operational costs of groundwater to farmers the cost of energy is the most important factor. In many states, the farmers are provided highly subsidized energy. Several studies suggest that despite their economic importance (Birner et al. 2007, p.207; Fan et al. 2008, p.164; Gandhi and Namboodiri 2009, p.24; Kumar 2005,p.44; Scott and Shah 2004,p.149) subsidized groundwater comes at the cost of groundwater over-extraction and future agricultural production. Inadequate water supply mechanisms add on to the difficulty in managing country's groundwater resources. In case of insufficient water availability farmers are forced to extract groundwater. Inadequate canal irrigation system, open earthen ditches, improper irrigation system designs, leakages in supply lines have all contributed in increasing the share of groundwater in irrigation (USDA, 2012, p.8).Groundwater management problems have exacerbated with growing rural-population pressure. According to Shah et.al. (2004, pp.149-154) supply side measures which include grants or low-cost loan finance for water well construction and irrigation hardware, support for the collection and dissemination of hydrogeological knowledge on groundwater occurrence and potential, technical evolution of waterwell pumps have made groundwater a likeable resource. With these factors it has become far more difficult to manage groundwater resources. Agriculture groundwater management through cooperative/collective action among farmers can take place but scholars viz. Wijayaratna (2002, p.25) believes that lack of providing subsidies and financial support for farmers and users' enterprises creates obstacles. Burak (1999, p.5) also acknowledges that having the government technical support is essential, especially for small WUAs (Water User Associations) as they face many financial challenges in adopting new and innovative irrigation practices. Groundwater management in agriculture can be made possible and effective if farmers are provided education, training regarding crops, cropping patterns and sustainable use of natural resources. Based on the study of Regner et.al (2006, p.13) failure to provide necessary training to farmers on irrigation management is an important problem in the field of water management success. Pereira et al.

(2002, p.178) also determine the responsibility of farmers for maintenance of canals and water resources as an effective component in water management. Ehsani and Khaledi (2003, p.15) mentioned about the role of education in promoting and increasing the efficiency of agricultural water .Panahi et al. (2009, p.3844) confirm that on increasing farmers' knowledge and skills through various training and extension programs (with new methods and considering the recent developments in the agricultural world) is necessary for improvising water use efficiency. According to Shiferaw et. al. (2003, p.13) this accelerated growth in groundwater exploitation and so called "silent revolution" has not been taken up seriously. It is a paradox that such a vast and highly valuable resource which is likely to become even more important as climate change sets in. The grave situation of groundwater depletion and quality degradation can be solved through effective common pool resource management but few factors prevent its management rather promote depletion**.**

According to Nibbering (2011, p.20), during the last two decades the developing world has shown a remarkable interest in common property resource management due to a growing concern for the sustainability of the exploitation of natural resources and the high costs involved in privatization or the establishment of state property regimes in (local) resource management. Economists and political scientists have devoted a great amount of effort to understand the use and management of common pool resources (McGinnis, 2000, p.595). Several approaches have been developed to analyze different solutions that address congestion/overexploitation of CPRs. The possible interventions can be organized broadly into three groups: the creation of property rights (Coase, 1960, p.44); the implementation of taxes and penalisations to incentivise users to reduce their consumption (Pigou, 1920); and finally, the creation of institutions and arrangements to incentivize users to internalize the congestion externality and cooperate in preserving these resources (Gordon 1954, p.126; Ostrom 1990, pp.207-211). Ostrom and other scholars suggest that communities can self-regulate (Ostrom and Gardner 1993, p.300). These studies have found some evidence that cooperation among the users of a CPR can emerge. Basically there exist two sets of solutions viz. command control approach and community or cooperative resource management. Examples of effective formal regulation and management of groundwater are rarer. However, there are cases such as groundwater basins in southern California where, in some but not all cases, users successfully organized themselves, with government backing, to manage water, including importing additional supplies of surface water, reversing seawater intrusion into aquifers, and actively managing storage and use of groundwater reserves (Blomquist, 1992). Community based autonomous efforts are emerging from some regions of India. The Andhra Pradesh Farmers Managed Groundwater System (APFAMGS) is one such large-scale effort purely community-driven at managing groundwater resources. Studies suggest that farmer's education, income levels and awareness, sensitivity about environmental issues play a vital role in cooperative management of resources. Local management of natural resources is also strongly advocated as local user groups are supposed to have a long term interest in the sustainability of local resources and command the knowledge systems and enforcement mechanisms required for optimal natural resources management. Moreover, joint management is considered to be worthwhile, for it can be superior to individual and competitive action. However, whereas common pool regimes may have performed well in the past, present day projects set up on the basis of collective management are often fraught with difficulties.

1.5. Research Gap

The studies have covered most of the aspects related to agricultural groundwater management but have not focused upon the inter-linkages between all the factors simultaneously. Also, not enough work has been done on this aspect in India and particularly with reference to Uttar Pradesh. The prior studies seem to be relevant but with rising water stress levels this problem needs to be in the light of current scenario. The studies have mainly discussed about the factors affecting groundwater depletion but have not elaborated about the type of governance or management mechanisms. Although, earlier studies have covered most of the aspects related to groundwater use and management in agriculture sector but still there lay a gap in literature. A wide variety of causes and impacts of groundwater use and management in agriculture sector need to studied and understood in detail. The present study is an attempt to fulfill this gap in the literature. The study is designed to make discussion into concerning issues of agriculture groundwater management in the wake of increasing dependence on groundwater and their depletion levels. This study intends to make contributions in deciphering the main reasons affecting groundwater sustainability and apart from this it also explores the socio-economic impacts with particular reference to agriculture sector.

1.6. Research Questions

Assessing the impact of agriculture practices on groundwater resources is important in order to understand the critical link between them. Examining this linkage enables in exploring the extent and citing the factors responsible for ineffective groundwater management. There is need for improvement in water usage patterns in agriculture production because groundwater which is its saviour especially in drought times would get depleted rapidly if not much attention is paid. As there exist no alternative for water, management of water seems to be the only possible solution to delay acute water scarcity.

During this study an attempt has been made to address the following research questions:

- What is the level of groundwater use in agricultural sector and what have been the trends so far?
- How does agriculture pose a threat towards groundwater resources and what factors are responsible for increased groundwater usage?
- What are the socio-economic impacts of groundwater stress in the study area?

1.7. Aims and Objectives

- To understand groundwater resources with reference to depletion, pollution and the linkage between resource use and their socio-economic impacts with particular reference to agriculture.
- To analyse the socio-economic factors that influence agriculture groundwater use and management.
- To suggest possible solutions for sustainable use of groundwater in agriculture.

1.8. Hypotheses

- The socio-economic factors influence use and management of groundwater in agriculture sector.
- Unmanaged groundwater resources have negative socio-economic impacts.
- There are combinations of formal, informal and user behaviour regulations that can improve groundwater levels and quality.

1.9. Research Methodology:

The present section is devoted to the methodological considerations adopted in the study and is a specification of the sources from where the data for different variables have been drawn.

1.9.1. Data Sources

During the research work, relevant data from both primary and secondary sources have been collected. A good volume of statistical data is involved in this research, especially information related to groundwater availability, use and depletion trends from Groundwater Year Books, brochures published by Central Ground Water Board and State Ground Water Board has been obtained. In order to ascertain the inequity in groundwater use, data on landholding wise use of dugwells, shallow wells and deep tubewells published in Minor Irrigation Census reports has been utilised. Considering the factors which influence groundwater use and management state wise secondary data, documents, reports have been collected mainly for the variables viz. landholding pattern, poverty levels, state domestic product, electricity consumption by agriculture sector, power tariff of agriculture consumers, environment performance. Regarding the impact of groundwater stress on agriculture, socio-economic condition of farmers, health hazards faced by them and farmer's willingness to pay for groundwater sustainability, primary level data is collected through an interview schedule. Compiling and analyzing such databases helped in arriving at a more complete understanding of the research problem.

1.9.2. Primary Data

Primary survey in a particular state or district of India is conducted so as to better understand ground level realities and provide the community a rational and practical solution for groundwater management.

a) Criteria for Selection of Study Area: The study area has been selected on the basis of data on dynamic groundwater resource use, availability and development of Uttar Pradesh provided by Central Ground Water Board (2015). Data depicts that Western Region of Uttar Pradesh has the highest level of groundwater development with an average of all districts being 84.77 percent followed by Central (72 percent), Eastern (70.70 percent) and Bundelkhand (65.14 percent). Further, in order to check which region has precarious problem of groundwater, an analysis of depth of water level / table has been done which reflects that western region leads with an annual average of 9.97m bgl, Bundelkhand has 7.74m while Central and Eastern region have 7.34m and 6.00m respectively. Micro assessment of the water depth levels reveals that in the Western region, Baghpat(21.69) has the lowest water table followed by Agra(18.51), Gautam Budhh Nagar(16. 39), Etawah (14.46) and so on. District groundwater brochure published by CGWB elaborates upon the dynamic groundwater resources of the district. The data highlights a grave fact that Baghpat is the only district in the state which has none of its block in the safe category. The overall groundwater development is one of the highest with 116.61 percent. Out of all the blocks in the district, the situation is serious in Binauli and Pilana, where groundwater development is 154.08 and 131.50 percent respectively. Baraut having groundwater development of 85.57 percent is the only less affected block, thus, it falls in semi-critical category.

b) Research Design: After the selection of the problem and the review of related literature, the survey method is chosen to carry out the research work for collecting the data and to arrive at conclusions. In order to select a representative sample for the study Multi-Stage Random Sampling Method is used for selecting area and households for data collection. The different stages of sampling are provided below:

Stage I- District: On the basis of indicator for water crisis i.e. groundwater development.

Stage II- Block: On the basis of indicator of water crisis i.e. groundwater development.

Stage III- Village: On the basis of geographically falling in an area more and less affected from groundwater depletion.

Stage IV- Households: Farmer households selected randomly in each village.

Structured interviews are used to obtain information regarding status of groundwater resources in the study area, changes in water availability, cropping pattern, behaviour of stakeholders towards groundwater resources etc. Interview schedule also included information on health issues/problems so as to understand the implications of worsening water quality.

c) Population: To collect the relevant data needed for the study, the researcher considered the farmer households of four villages namely Gurana, Vazidpur, Pura Mahadev and Mawi Kalan of Baghpat district, Uttar Pradesh.

d) Sample size: A total number of 300 farmer households were part of the primary survey in four different villages of Baghpat district.

e) Statistical Techniques: The secondary and raw data obtained from the interview schedules are statistically processed using STATA 13 version. Means, Standard Deviations, coefficient of variation, Correlation coefficients has been calculated. Student's-test and chi-square test was applied to know the significant differences population and sample. Further, gini coefficients, growth rate (GR), simple and multiple regression, dummy regression model and Logistic regression are used to reach a definite conclusion. Further, socio-economic vulnerability index and groundwater stress index have been constructed.

Growth Rate (GR)

Growth Rates (GR) of electric pumps has been calculated using secondary data from 3rd 4th and 5th Minor Irrigation census. The simple formula for estimating is:

$$\mathbf{GR = (Ending\ Value/Initial\ Value)^{1/n-1}}$$

Ending Value = Year 2013-14

Starting Value = Year 2000-01

n= no.of years = 13

Gini Coefficient

Gini coefficient is a statistical measure of distribution that is used as an indicator of economic inequality. It is also known as the Gini ratio or Gini index ranging between 0 to 1. A value of 1 shows the highest degree inequality while a value of 0 depicts perfect equality.

Socio-Economic and Ground Water Stress Index

These indexes have been estimated using Iyengar and Sudarshan (1982) methodology, wherein the selected indicators have been normalized within the range of 0-1. Making an assessment of the qualitative indicators is tough without converting them into a specific scale so minimum and maximum values (goalposts) are set on a scale of 0 to 1 by using the below mentioned formula:

$$SEVI\ or\ GWSI_{ijk} = \frac{X_{ijk} - min_k X_{ijk}}{max_k X_{ijk} - min_K X_{ijk}}$$

Where, i= Variables (1, 2, 3……., I), j= Components (1, 2, 3……., J) and k= Villages (1, 2, 3……., K). The numerator measures the performance of the jth entity with reference to ith indicator. This measures the relative performance between two entities. The denominator in the above equation is simply the range of the indicator and aids in estimating the performance level.

In case the indicator has a negative relationship with the component the below stated formula is used:

$$SEVI\ or\ GWSI_{ijk} = \frac{X_{max} - X_{ijk}}{max_k X_{ijk} - min_K X_{ijk}}$$

The weights are determined by-

$$Wj = c/\sqrt{var\ (xij)},$$

Where c is a normalizing constant such that

$$c = [\sum_{j=1}^{j=K} 1/\sqrt{\underset{i}{\text{var}}(x_{ij})}]^{-1}$$

After this step, index is generated by summing up individual score and dividing it by number of indicators.

Multiple Regression with Dummy Variables

The following regression model is used to assess the association and effect of different socio-economic, hydrological variables on agricultural output within the sampled villages:

$$Yi = a + \beta_1 X_i + e_i$$

Over here, Y_i = dependent variable total value of output (log)

a= intercept

X_i = matrix of explanatory variables (viz. village, land size, groundwater stress, income, caste, education)

Logistic Regression

The following logistic regression model is utilised to estimate the determinants of health hazards in sampled villages and the probability of WTP for managing groundwater by the farmer households within the sampled villages:

$$Y_i = ln\frac{P_i}{1 - P_i} = \alpha_i + \beta_i X_i + e_i$$

Wherein, Y_i= Dependent variable (if the household has a member suffering from water-related disease in one model and whether the farmers household's is WTP i.e. above Rs.50 for improvement in groundwater ecosystem in another),

X_i = the matrix of explanatory variables comprising all social , economic factors and hydrogeological factors,

β_i=co-efficient of unknown parameters

α =intercept,

e_i = is the error term

1.10. Significance of the Study

The researchers recently concluded that Earth's population are consuming groundwater quickly without knowing when it might run out as the physical and chemical measurements of groundwater are insufficient (NASA news,2015).Another report by NASA's Gravity Recovery and Climate Experiment (GRACE) satellites show that India is worst hit by groundwater depletion. It highlights that climate change and population growth is expected to intensify the problem, therefore there exists an urgent need to preserve groundwater.

Conducting a research study on this global issue with reference to agriculture (main user of groundwater) in India would help in creating awareness. An average groundwater user (individual farmer) in India has little or no formal knowledge about the real water crisis which we are facing or would be facing. Farmers draw water without any limit from a shared aquifer, which is often a non-excludable public good; therefore, one person's water use imposes a negative externality on other individual's water availability and thus making water depletion becomes a classic example of a tragedy-of-the-commons (Alfredo et.al. 2011).This study pinpoints the causes for water depletion and degradation due to agriculture practices and promote stakeholders to take actions accordingly. An analysis of the weaknesses in legal and institutional setup done during the research enables to suggest possible solutions for effective groundwater management. The study is significant in terms of laying emphasis on active management of groundwater in agriculture which could prevent tragedy of commons and achieve intra-generational and inter-generational equity. The study promotes groundwater resource management so as to prevent economic impacts on agriculture. In addition, the findings suggest that use of groundwater by any sector of the economy will have socio-economic, health implications on the whole population as groundwater is a common pool resource. Study findings also help in identifying and prioritizing local capacity-building needs.

1.11. Chapterisation

Chapter I- Groundwater and Economic Development: Theoretical and Conceptual Framework- It highlights the importance of natural resources particularly groundwater in economic development. It focuses on the theoretical and conceptual understanding of common pool resources particularly groundwater and presents the basic framework of study.

Chapter II- Groundwater: Stress, Governance and Implications- Attempts to analyse the set of drivers and impacts of groundwater depletion/degradation. The different governance and management mechanisms regarding groundwater resources are also detailed out.

Chapter III- Groundwater: Extent and Dynamics behind its Management- Through secondary level data and literature, this chapter presents the status, extent and dynamics affecting management of groundwater resources across states in India. It also highlights the relationship between land distribution and groundwater accessibility.

Chapter IV- Socio Economic Profile of Baghpat, Uttar Pradesh- The social and economic status of sampled farmer households in different villages is presented.

Chapter V- The Various Dimensions of Agriculture in the Surveyed Area- The chapter made an attempt to observe India's agrarian crisis through the lens of primary data collected from different villages of Baghpat district, Uttar Pradesh.

Chapter VI – Groundwater Scenario and Perception of People in the Surveyed Area- It analyses the perception of farmer households about groundwater availability, accessibility, causes of water decline and response to depletion threats. It also assessed groundwater stress levels in different sampled villages and across land size groups.

Chapter VII- Willingness to Pay for Managing Groundwater by Farmer Households- It presents an outline of contingent valuation approach and estimates the Willingness to Pay (WTP) of farmer households for managing groundwater resources in the region and also encapsulates its determinants.

Chapter VIII- Major Findings and Policy Recommendations-It present the key findings, policy suggestions, limitations and future scope of the study.

1.12. Conclusion

Growing population needs combined with insignificant improvements in water efficiency or water resource management would lead to increased water abstraction, particularly, groundwater. Studies suggest that irresponsible use of scarce water would hamper the economic growth of the country so there is an urgent need to solve this issue. As water does not have an alternative, effective resource management seems to be a way out. Therefore, this study focuses on generation of improved understanding of groundwater management, identification of gaps and developing coping strategies with special reference to agriculture. In order to further explore the linkage between the groundwater management and agriculture there is a need to decipher factors affecting resource management and the impacts groundwater stress would have on people. Therefore, the prime focus of the study is to analyze the salient socio-economic factors that influence groundwater use and the socio-economic, health implications of groundwater depletion and degradation. In addition, the study proposes possible solutions for sustainable use of groundwater in agriculture and allied fields.

Chapter II

Groundwater: Stress, Governance and Implications

2.0. Introduction

Water resources play an important role by virtue of their functions for human development, health, food security, industrial production, balance of ecosystem and overall economic development. Water available for use is present in rivers, lakes or oceans and also lies underground which is termed as ‘groundwater’. It represents one of the most important water sources in the world as more than two billion people depend directly upon aquifers for drinking water and 40 percent of the world’s food is produced by farms irrigated through groundwater (UN, 2016). However, due to their common pool resource characteristic and certain other socio-economic, behavioural, institutional and physical factors, groundwater all across the globe is getting depleted and degraded.

2.1. Groundwater Stress and Implications

Globally, irrigation accounts for more than 70 per cent of total water withdrawals and for more than 90 per cent of total consumptive water use (Siebert, 2010, p.1863).Despite its huge availability and importance, groundwater resources are in deep crisis and its stress is rising even in water rich countries (Famiglietti, 2014, p.945). Roughly one-third of the world’s population now lives in water-stressed areas, and nearly a billion people still live without access to safe drinking water (World Economic forum, 2015). Groundwater extraction has increased more than 300 per cent since past fifty years (UNESCO-IAH, 2015, p.6). Groundwater, being a common pool resource is readily available to everyone and in addition to this subsidized electricity, absence of clearly defined property rights lead individuals to have unlimited access to groundwater. Consequently, most of the major aquifers in the world’s arid and semi-arid zones, that is, in the dry parts of the world that rely most heavily on groundwater, are experiencing rapid rates of groundwater depletion. Groundwater is being pumped at a rate faster than its replenishment rate. Some of the largest aquifers in the world viz. North China Plain, Australia’s Canning Basin, the Northwest Sahara Aquifer System, the Guarani Aquifer in South America, the High Plains and Central Valley aquifers of the United States and the aquifers beneath northwestern India, Middle East are deteriorating at a rapid pace (Famiglietti, 2014,p.946). UNEP (2008) stated that India is one of the country which is likely to run short of water in next 25 years and its water scarcity is expected to worsen as the overall population is expected to increase to 1.6 billion by year 2050. The overall stage of ground water development in the country is 62percent. The status of ground water development is very high(>100percent) in the states of Delhi, Haryana, Punjab and Rajasthan which implies that the annual ground water consumption is more than annual ground water recharge. In the states of Himachal Pradesh, Tamil Nadu and Uttar Pradesh and UTs of Daman & Diu, and Puducherry, the stage of ground water development is 70percent and above. In rest of the states / UTs the stage of ground water development is below 70percent (CGWB, 2014).Data on groundwater depth(in year 2014) reveals that the situation is quite deplorable as out of the total wells analyzed 30.20 per cent wells are showing water level less than 2 m bgl (metres below ground level), 32 per cent are in the depth range of 2-5 m bgl, 22 per cent wells show depth range of 5-10 m bgl, 11 per cent fall in the depth range of 10-20 m bgl, 3 per cent have range of 20- 40 m bgl and only 2 per cent have water level more than 40 m bgl (CGWB,2015). Considering the data on administrative units, the report mentions that out of total (6607) assessed administrative units, 1071 units are Over-exploited, 217 units are Critical, 697 units are Semi-critical, and 4530 units are Safe. Numbers of over-exploited and critical units are significantly higher in Delhi, Haryana, Himachal Pradesh, Karnataka, Punjab, Rajasthan Tamil Nadu and Uttar Pradesh. Focusing on Uttar Pradesh, data reveals that over exploitation of ground water especially in western parts of Uttar Pradesh has led to decline in water levels over the past few years. The State Ground Water Department has categorised the blocks on the basis of level of development of ground water and water level trends. Out of 22 over exploited and critical blocks, 19 blocks are located in western parts of the state in districts of Agra, Aligarh, Baghpat, Bareilly, Badaun, Etah, Farrukhabad, Firozabad, Jyotibaphulenagar, Moradabad and Saharanpur. The water level declining trends in these blocks are about 30 to 55 cm/year in either pre or post monsoon period or both. Out of 53 semi-critical blocks, 28 are located in western U.P. On the other hand, in the Canal Command areas, the water logging and related problems like salinization & degradation of soils are posing a threat . The above statistics suggest that India’s groundwater challenge is of an unprecedented scale and complexity. It is not simply a water resources problem, but a multi-sectoral (e.g., agriculture, energy, water, and environment) urban and rural economic development challenge, with different hydrogeological conditions and socioeconomic conditions that will require different sets of solutions.

Though, there are several causes of rising groundwater stress but it is necessary to assess the contribution made by its biggest user viz. Agriculture. It is the biggest consumer of groundwater (IDFC, 2011, p.1) as well as one of the biggest sufferers of groundwater stress.

Sekhri (2011, p.13) found out that a 1 meter decline in groundwater level in a year reduces foodgrain production by 8 per cent, water intensive crop production by 9 per cent and cash crops by 5 per cent. Zaveri et.al (2016, p.21) elaborated the impact of groundwater stress by stating that gradual decline in groundwater levels may accentuate poverty and food insecurity in rural India. The dependence of irrigation on groundwater in India increased with the initiation of the Green Revolution, which promoted intensive use of inputs such as water and fertilizers to boost farm production. During this time, rather than extending surface water irrigation to un-irrigated regions, policymakers began providing incentives for groundwater extraction. IDFC (2011, p.9) stated that the total area irrigated by wells increased by 61 per cent during 1950-2009. Groundwater irrigation covers more than half of the total irrigated area and is responsible for seventy per cent of production and supports half of the population (World Bank, 1998, p.1; Shah 2009, p.2). However, studies have now confirmed that over-extraction of groundwater is depleting aquifers across the country, and water table declines are becoming ubiquitous (Tiwari et. al., 2009, p.3; Livingston, 2009, p.5; Shah, 2009, p.4 and Fishman, 2011, p.2). In fact, the rates of depletion in India are probably the highest in the world (Aeschbach-Hertig and Gleeson 2012,p.854).The CGWB estimates that 92 percent of the groundwater extracted is used for irrigation and 15 percent of the administrative blocks are using more water than is replenished (Jha and Sinha, 2009, pp.1-2). Despite growing scarcity, groundwater unsustainable irrigation in India remains active and few management steps taken have not been extremely successful. Groundwater usage in agriculture tends to exhibit a competition on “who pumps out more and how quickly”, either through deeper wells or larger pumps. With increasing demand, subsidized electricity, lack of awareness, low level technology adoption, less capital investment on water saving techniques/devices etc. have inversely affected groundwater management in agriculture sector in the country. This arena of competition, conflict and incomprehension will only grow the atrocities of largely unseen, invisible and fugitive resource. Foster and Chilton (2003, p.1958) point out, groundwater resource degradation is “much more than a localized problem” and it threatens the sustainability of the resource base, on a “wide-spread geographical basis”. Therefore, Shah (2009,p.5) describes an urgent need towards groundwater management and addressing the various issues viz. water-energy nexus in developing groundwater governance in response to tackling groundwater anarchy while sustaining and improving South Asia’s irrigation economy.

Groundwater depletion and degradation has massive impacts on environment, economy and human beings. It has major environmental, pecuniary and spatial impacts. Environmental implications encompass soil salinization, salt water and sea water intrusion, land subsidence, and drying up of lakes and vegetation in different components of the country (Watto and Mugera , 2016, p.195)**.** The depletion affects surface water as the water desk is largely at or slightly above the floor surface. Dropping water tables consequences in drying of wetlands. Further, as water tables drop springs and seeps dry up, diminishing streams and rivers even to the point of dryness. Thus, excessive groundwater elimination leads to the equal results as diversion of surface water. Over a while, groundwater has leached cavities in the Earth. Where those spaces are filled with water, the water allows aid the overlying rock and soil, but as the water desk drops, this support is lost. Then there can be a sluggish settling of the land, a phenomenon called land subsidence. Another sort of land subsidence, the prevalence of a Sinkhole, may be sudden and dramatic. A sinkhole occurs when an underground cavern, tired of its supporting groundwater, suddenly collapses. Sinkholes may be 300 feet (91 m) or more throughout and caverns through historic beds of underlying limestone. Estimated 4000 sinkholes have passed off in Alabama alone, some of which have "consumed" buildings, livestock, and sections of highways. A lowering of the water table or a rapid charge of groundwater elimination might also reduce the pressure within the aquifer permitting salt water to go with the flow back into the aquifer and therefore into wells. Saltwater intrusion is hassle at many locations along U.S. Coasts (Sah, 2016, p.7). Prominent effects of groundwater depletion include reduced glide to floor water structures and ecosystems; loss of productiveness of groundwater wells; subsidence of land and floor disasters; and degradation of groundwater quality.

Various pecuniary impacts viz. Growing pumping prices even as reducing land values also are very distinguished. Migration and prospective social conflicts are among the capacity spatial affects. In addition, there are also severe health affects as groundwater is the principle supply of consuming water in India. Ground water can end up contaminated from natural assets or numerous sorts of human sports. Residential, municipal, commercial, commercial, and agricultural activities can all have an effect on ground water high-quality. Contaminants may also reach floor water from activities at the land surface, consisting of releases or spills from stored industrial wastes; from sources beneath the land floor but above the water table, including septic systems or leaking underground petroleum garage systems; from systems under the water desk, inclusive of wells; or from infected recharge water. The consequences of infected ground water or degraded floor water are often severe (OECD, 2017, pp.3-4). For instance, estuaries which have been impacted via excessive nitrogen from floor water assets have misplaced crucial shellfish habitats. In terms of water deliver, in a few instances, ground water infection is so excessive that the water supply need to be deserted as a source of drinking water. As groundwater generally movements slowly, contamination frequently stays undetected for lengthy intervals of time. Different metals/pollutants discovered in groundwater viz. Mercury, fluoride, arsenic and agro-chemicals have different tiers of associated fitness dangers. Mercury is mentioned to reason impairment of mind functions, neurological disorders, and retardation of increase in youngsters, abortion and disruption of the endocrine machine. High fluoride content frequently causes flourisis which may be categorized as skeletal and dental respectively. This can be often detected from symptoms viz. broken joints and bone deformities, yellowing of tooth. Arsenic contamination of drinking water causes an ailment known as arsenicosis. Arsenic contamination is with the aid of a ways the biggest mass poisoning case inside the world putting 20 million human beings from West Bengal and Bangladesh at threat although some different estimates positioned the discern at 36 million human beings. Considering pesticides, they stated that insecticides harm the liver and anxious system. Drinking water containing bacteria and viruses can bring about illnesses inclusive of hepatitis, cholera, or giardiasis. Methemoglobinemia or "blue child syndrome," an illness affecting babies, can be caused by ingesting water this is excessive in nitrates. Benzene, an element of gasoline, is a known human carcinogen. The extreme health outcomes of lead are widely recognized studying disabilities in kids; nerve, kidney, and liver problems; and pregnancy dangers (EPA, 2018, p.8; Wang et.al. 2012, pp.7-8; OECD, 2017, p.6)**.** The groundwater has a socioeconomic value in itself. The natural excellent of groundwater makes its use valued in industry, and it can offer environmental advantages as well as for the boom of flora. In addition to this, prohibition from leisure use (e.g. Swimming, fishing, seafood amassing), seaside closure, impacts on aesthetics, cultural and spiritual values (WHO ,2008, p.15).Losses in fishing, boating, rafting and swimming activities to other tourism activities or to other ventures with superior water quality are also some of the effects (OECD, 2017, p.5).Further, myopic behavior by means of man or woman producers as a consequence leads to collective inefficiencies(Gisser and Sanches, 1980, p.336). The power for self-sufficiency in some strategic plants advocated by low energy expenses has placed heavy pressure on the quantity and quality of ground water assets. The poor effects of present day human practices will take a toll in coming years. Due to these blessings fortify the want for protection of groundwater. Focusing on agriculture sector cited that agriculture is each a motive and a victim of water scarcity. Unsustainable groundwater use will have long term impacts on agricultural production in areas consisting of South Asia, in which a growth in groundwater-based totally irrigation within the 1980s and 1990s led to a chief boom in agricultural production that is now restrained by aquifer depletion. The essential worry is that agricultural manufacturing will decline in tremendously populated regions at a time when call for is rising, and the issue of food security is coming to the fore in all regions (FAO, 2008). When the available food supplies diminish due to cyclic drought events or long-term climate variability, hardship is exacerbated until wellbeing and livelihood are eroded (Robbins, 2013, p.2).The developing scarcity and competition for water stands as a prime risk to future advances in food production and poverty relief. Food production is in all likelihood to be adversely affected specifically in the semiarid areas, which encompass of Asia's foremost breadbaskets, the Punjab and the North China Plain. Groundwater assets and food production are inextricably related because it guarantees food security by supplying water for irrigation. It is anticipated that international food production will boom through 60-90percent by 2050 to satisfy the call for created by means of population growth and changing diets. The intensification of crop production is likely to generate in addition soil erosion, groundwater depletion and salinisation, immoderate nutrient and pesticide leaching, and aquatic ecosystem pressure. Farmers will want to maximize water productivity, to cooperate with efforts to preserve land sources and beautify groundwater recharge, and to introduce less water-intensive crops (IAH, 2015).Another predominant effect of groundwater pressure is that the groundwater depletion pose extra situation for socio-economic equity inside the access to this resource. Her empirical analysis signifies the issues for the livelihoods of farmers, whilst the fee of depletion is disproportionately borne through the resource-poor farmers as they're unable to spend money on capital and technology and are subsequently denied the benefits of groundwater irrigation this is subsidised by way of free electricity. This scenario is perpetuated with further shortage main to unequal economic returns and, eventually, takes the most exploitative form where the “massive landlords” also become “water lords” via surplus accumulation, forcing the small and marginal landholders to emerge as landless agricultural labourers. The declining water desk may not handiest boost the marginal operational price, but also provide rise to a scenario of faded water availability, resulting in loss of farm output and reducing net returns (Sarkar, 2011, p.64). Elaborating further, the groundwater associated problems has cause marginalisation of farmers. Key elements of marginalization are unequal financial capital of the farmers to put money into deep drilling and in water-saving localized irrigation, the small landholding size, differing access to drilling allows, from time to time depending on the social and political weight of the respective farmer. Due to this, many farmers have been pressured to sell their land which has contributed to the destabilization of families and migration to city regions.

Thus, literature indicates that groundwater degradation and shortage have implications starting from ecological consequences such as salination and desertification, to social inequalities to political demanding situations, in addition to monetary tensions (Houdret, 2006, pp.9-11).

2.2. Groundwater Governance and Management

Common-pool resources may be defined as goods having universal accessibility and (non-)rival consumption. These characteristics may be properties that are inborn or inherent in the goods themselves, or have been assigned to goods through societal consensus/ agreement or through political decision. In the seasoned economic literature the central attributes of public goods i.e. non- excludability and no rivalry (Samuelson, 1954, pp.387-389) have been regarded as the key drivers of market failure, due to which government intervention in their provision became necessary. The issue with common pool assets and public goods lies in their restricted excludability. Accordingly, costs can't be charged and thus private arrangement through the market isn't achievable. Groundwater, being a common pool resource suffers from market failure problem. It primarily possesses four properties viz. invisibility, open-access, indivisibility and finite nature. It is these characteristics which make its access, use and thereby exploitation easy. Due to its invisible nature accurate estimates of its availability are absent. This prevents effective monitoring and management. In addition, groundwater is easy to access as anyone can drill and pump out water as per requirement. Absence of property rights in case of groundwater has posed a serious threat for its conservation.

Therefore, before proceeding further, it is necessary to understand about property rights in an elaborated way. Baltzer (2002) mentioned that there are essentially three different ways a property right can be assigned viz. to an individual, to a group of individuals collectively and to no one. These three possible “pure form” property rights regimes include- Private property rights wherein all property rights (i.e. all the elements of a property right) are vested with an individual. Common property rights in which all property rights are assigned to a group of individuals collectively. In this regime, every member of the group does not possess the rights individually but jointly with the other members of the group. Open access regime is one where all property rights are held by no one. In other words, no property rights are defined. Nibbering (1997, p.21) stated that the "physical or technologically induced character" of groundwater gives it the economic attributes which leads to its treatment as a common pool resource. Groundwater resources belong to the category of common goods/property: they are non-excludable (i.e., users can not be prevented access to the good), unlike private goods, and they are usually rivalrous goods (i.e., the use of the good by one user can lower the quantity available for the other users), unlike public goods. However, within limits all users can derive benefits jointly from the resource. Due to this jointness of use, groundwater and other common pool resources also resemble public goods. Jointness of use follows partly from the fact that common pool resources, and groundwater in particular, tends to be indivisible: it cannot be partitioned among private owners. The land holding (legally no separation between land rights and groundwater rights) can be demarcated and divided among private owners, but the groundwater held in the land is mobile and physically interconnected, a characteristic of fugitive resources such as shoals of fish, wildlife or air in the atmosphere. Such conditions make it difficult to regulate access to groundwater (common pool resource) and to exclude others from its use. These kind of rivalrous situations give birth to congestion externalities: water withdrawal in an aquifer by a particular user causes the water table to fall, resulting in increased pumping costs for all users. As a result, if each user exclusively thinks in terms of his or her immediate individual costs (the "cost signal", given by the market) and continues extracting water, the continuous increase in costs eventually leads the entire system to become unprofitable, and the resource to get degraded (sometimes even permanently). In reality, all users are aware of this mechanism, they have no incentive to individually restrict their withdrawals and share the benefits of their virtuous or cooperative behaviour with all their rivals. The individual's optimal strategy of withdrawing water without restraint is a "prisoner's dilemma", where the outcome of users pursuing their self-interest/motive is collectively a suboptimal situation. Such a "pumping race" generates several adverse repercussions with negative economic impacts, such as cost increases, gradual decrease of benefits to users, environmental consequences such as the sinking of the water tables, deterioration in water quality, saltwater intrusion, and social outcomes including the exclusion of the less-equipped users (Nibbering, 1997, pp.20-21).

Experts who have studied groundwater use around the world tend to agree that too little is known about the institutions and policies that govern the use of these resources (Mukherjee and Shah, 2005, p.328). Nevertheless, innovative approaches to groundwater management have been developing in many parts of the world over the past decade (Varady et.al, 2011, pp.6-7). In the past decades, the classical governmental approach towards groundwater resources management has been based on a plan-and-control and engineering-centered approach. The classic groundwater resource management consists of a wide set of assessment and planning, controlling, and behavior-changing instruments, and is based on the existence of various institutions (Tuinhof et al., 2002, pp.3-4; Kemper, 2007, p.155; Theesfeld, 2011, p.87). The tool-kit includes technical instruments (surveying, groundwater quantity and quality monitoring and modeling, other diagnostic analyses, sustainable aquifer yield estimations), managerial and planning instruments (IWRM-plans, land use and spatial planning, environmental impact assessment, groundwater protection zoning), regulatory instruments (property rights, licensing, legislation),economic instruments (groundwater pricing, environmental taxes, tradable rights and groundwater markets) and behavior-changing instruments (training, information sharing) (Varady et.al, 2011, p.7). Broadly, there are three general approaches to groundwater management viz. collective action or community-based approaches, instrumental approaches, and indirect approaches. Although the solutions to CPR problems may seem impossible, a substantial body of work over the past 30 or more years has shown that local collective action can successfully meet the challenges, under certain circumstances. Ostrom believed that common pool resources like groundwater can be best protected through cooperation/collective action approach or management structure. In water, the positive stories of local collective action have primarily involved traditional surface irrigation, such as the tank systems of southern India or the famous Subak systems of Bali, where mutual monitoring is feasible. However, there are also examples from groundwater. The traditional management of small-scale qanat systems spread across North Africa and the Middle East provide good examples as well as some traditional systems have worked well in drier parts of West and East Africa. Grabert and Schagler have summarized evidence of collective action success in modern groundwater systems in South Asia, Yemen, and Egypt. Although Grabert & Narasimhan note that the success stories are limited, they also stress that, in those examples, collective action was the only option that did work. Other authors have highlighted the potential for local participation in management through the equivalence of water user associations, for example in Mexico, Jordan, and Spain (Delaney and Jacobson, 2015, p.48-50). In India, successful example of collective action is found in Andhra Pradesh wherein APFAMGS project inverts the conventional approach to groundwater management and instead of an external entity determining and actively policing the limits to groundwater withdrawal, encourages farmers to collect local water data and make collective resource use decisions (IWMI, 2012, p.2).The key problem in the success of collective or community-based approaches to groundwater management is that the number of users of a particular aquifer can be high and their location geographically spread, thereby increasing the costs of cooperation. In addition, the invisible and dispersed nature of groundwater renders difficulty in monitoring the availability as well as use, thereby complicating efforts by local users to jointly set and enforce rules (Giordano, 2009, p.19).

Two instrumental approaches that are most often used and discussed in groundwater management are: assignment of regulations and water-use rights (including rules, permits, entitlements, licenses) which establish the privileges, restrictions, and obligations of groundwater users and second approach is use of pricing(includes taxation). In the first approach, regulations codify and specify how users have to use groundwater. As far as rights are concerned, they are usually bestowed on individuals or groups and range from being temporary or permanent, usufruct to fully tradable. The establishment of groundwater-use rights has been more common in developed countries than in the developing ones. Water pricing, a major topic in the general literature appears not to have seen widespread use in groundwater. It is true that groundwater markets are common in South Asia, China, and elsewhere. However, there is some debate as to whether they are truly water markets or rather markets for water services (e.g., pumping). The three challenges to the successful implementation of instrumental approaches are in acquiring sufficient information to set overall abstraction levels or prices (if prices are not market set), in establishing acceptable methods for determining how abstraction rights are distributed between users, and in developing mechanisms to enforce rules.

When groundwater institutions are discussed, we normally think of those institutions which are directly related to the groundwater sector. However, the institutional and policy arrangements that impact groundwater extend far beyond the sector itself. The policies from two particular sectors stand out in this regard are—energy and agriculture (Giordano, 2009, p.19). India provides the best example of the potential impact of energy policy on groundwater outcomes. From the 1950s through the 1970s, the use of electric tubewells was encouraged in India by both the government and external lenders as a means to agricultural and economic growth. As tubewells spread, metering and fee collection became a major challenge, and a flat tariff system was introduced partially in response. The flat tariff reduced transaction costs in fee collection, but also removed marginal incentives for farmers to use electricity and water efficiency. The eventual outcome was that power for agricultural groundwater use has become essentially free in India's major groundwater-using regions, encouraging overuse and simultaneously draining the funds of state electricity boards. A World Bank study concluded that power sector subsidy in India amounts to Rs 270 million per year (US$6.0 billion), two and half times the annual state expenditure on canal irrigation. The government of India has embarked on reforms, one of the main components of which is agricultural power supply metering, to address the linked energy-groundwater problems. Although few states have agreed to reforms, an initial assessment of one which has, West Bengal, suggests that they are having an impact on both the volume of groundwater extracted and the efficiency of its use. Rather than power metering, another Indian state, Gujarat, has instead decoupled agricultural electricity supply from rural domestic and commercial electricity supply. They ration the number of hours of electricity supplied to the agricultural sector and let households and other sectors have unrestricted access. Again, there has been a direct impact on the volume of groundwater extracted. Similarly, there is evidence that in diesel-dependent eastern India, the rise in diesel prices in the early 2000s led to decline in irrigated area. Although the extent to which India's groundwater overdraft problem is energy related is not known, it is clear that energy costs, and therefore energy policies, do play a significant role in groundwater-use decisions. A second important policy arena with impacts on groundwater is agriculture. The choices farmers make about the type and quantity of crops they produce is often heavily influenced by national agricultural policies. In some cases, the connections between these policies, farmer decisions, and water use are relatively easy to trace for example the Conservation Reserve and Payment-in-Kind Programs in the United States provided incentives for farmers to reduce cropping, thereby reducing groundwater use in the Ogallala aquifer. The connection between groundwater use and agriculture has also been explored with launch of the Green Revolution. In terms of yield increase, the Green Revolution was clearly a success. However, the new hybrid varieties typically required new farming systems. These systems often required greater control and use of water, and in many cases, this was facilitated by groundwater. In fact, it has even been argued that the Green Revolution was first of all a tubewell revolution which in some senses gave rise to current groundwater outcomes (Shankar, 2011, p.38). The difficulties in implementing community-based and instrumental approaches to groundwater management have already been highlighted. Indirect approaches are not necessarily any easier. Thus, there is a need to first assess the problem causing factors and then devising an effective solution for maintaining groundwater sustainability.

2.3. Groundwater Management Issues

Three seminal works on understanding enabling factors are of Wade (1988), Ostrom (1990) and Baland and Platteau (1996). These works have several insights in common for understanding the 'hows' and 'whys' of (un-)sustainable management for CPRs (Fisher et.al., 2010, p.1256).Despite efforts to reform management of water resources, groundwater levels have continued to decline steadily in key aquifers across India, leading to serious environmental concerns and impacts. While several studies have mentioned the importance of effective groundwater management as the viable solution some also focus upon the factors which influence groundwater management. Working on the same path, our study tries to assess various factors behind farmer's over-consumptive water use and incomprehension towards groundwater management (Msangi and Cline, 2016, p.1).Groundwater management in agriculture sector in India faces a set of challenges ranging from administrative, social, economic, and political. Many studies have focused upon several hydrological (Gupta, 2009, p.1; Srivastava et al., 2014, p.262), socioeconomic (Nagaraj and Chandrakant, 1997, p.42; Sarkar, 2011, p.46), institutional (Ballabh, 2003, p.467) and policy (Sekhri, 2013, p.13; Sarkar and Das, 2014, p.65) related aspects of groundwater management. India's Central Groundwater Board cites few reasons for this stress viz. increasing population, deficient monsoons, unregulated wells, and economic pressures such as farmers' dependency on loans for costly agricultural inputs and fluctuations of product value on international markets (CGWB, 2006). The various ***factors*** influencing groundwater use and management are as follows.

2.3.1. Institutional Factors

Open access resources are the ones which lack ownership and control. Access to them is unregulated and free. Baland and Plateau made a distinction between open access and common property resources. Starting with the aspect of water rights in agriculture sector, studies suggest that CPR status of groundwater is one of the prime reasons for its rapid depletion and degradation. Many growers and irrigation districts are reluctant to adopt water efficiency practices because they believe that conserved water may be made available to other users who eventually could start claiming a certain right over the water. This is the reason why numerous irrigators fear that conserving, and thus sharing, their water could lead to a loss of their water rights. Again, it is a question of education and regulatory efforts that must be carried out in order to help farmers and other water users to cooperate and reach win-win agreements. The lack of well-defined property rights, the invisibility, and the complex flow characteristics of ground water makes it very difficult to monitor the use of groundwater. Water rights and land rights are currently linked, in order to protect groundwater resources there is a need to separate both of them. The World Bank (1999, p.4) indicates that tying water rights to land rights has implications for access to groundwater. At the field level, due to the characteristics of groundwater as a common property resource, larger farmers with higher pumping capacity and deeper tube wells have a disproportionate claim over the resource than others. Such legal framework often leads to indiscriminate use of groundwater resources and also implies that only the land owners own groundwater. Consequently, the landless – who constitute more than 30 percent of the rural farm population – do not enjoy private ownership of groundwater or other water rights (Moench, 2003, p.152). Such inequity has paved way for development of "**water market**". Singh (2003, p.9) indicates that water markets partly address the issue of water availability to small farmers by providing them access to groundwater. Farmers who do not have their own wells or cannot afford pumping sets can have access to groundwater irrigation through water markets. These markets have helped the farmers in increasing their potential income and have also benefitted the society by incrementing the per unit production. But in such cases, the large farmers sell the surplus water, hence, the value attached to the groundwater by the small farmers is much more than the sellers in the groundwater market. Water markets and trading can only partly mitigate the inequalities in access to groundwater resources due to lack of ownership of land (Jeet, 2005). Though water markets exist, they are mostly limited to localized water trading between adjacent farmers. Literature suggests that these water markets are typically spontaneous (initiated by private individuals to achieve mutual gains), informal (transaction of water takes place without any legal bindings and to get mutual benefits between the buyers and sellers), unregulated (no strict regulation is followed), localized (mostly functioning at the village level), fragmented (geographical separation of sellers) and seasonal (demand varies across seasons) (Tiwari and Akinapallii, 2014, p.3). Data from NSSO 54th Round on cultivation practices at the household level reveal that about 46 per cent of the area irrigated under five major crops was based on hired services from other households, which indicates the extent of water markets development for irrigation in the country (TERI, 2008; Mukherjee, 2007) as cited in Tiwari and Akinapallii (2014, p.4).Water trading remains informal in the sense that there are often no formal methods or agreements. This hinders the reallocation of water for more productive use. Existing water markets are strongly biased towards sellers and do not provide bargaining power to the buyer. This has given sellers a degree of monopoly in the markets (Easter et. al., 1998; Shah, 1993; Palanisami, 2009). This monopoly power also helps sellers not only in raising prices but also in compromising the quality of service they offer (Mohanty and Gupta, 2002, p.3). Overall, the absence of clear property rights on groundwater has lead to the conflict of interests. The large farmers, by virtue of open access, exploit all the available resource stocks. Finally the time would come when the driller would realize that it is no more economically viable to drill because the extraction rates would go beyond the sustainable yield rates. This may lead to drying up of the aquifers. Apart from this, countries viz. Oman, Iran, Saudi Arabia, Israel etc. has formulated laws and administrative regulation to control agricultural groundwater use. But in a country like ours where non-autocratic rule prevails and there is huge number of groundwater users in agriculture, groundwater usage cannot be administered in this way. Though steps have been taken in the form of passing a ‘Model Bill to Regulate and Control the Development of Groundwater’ was circulated in 1970s but it has not been enacted upon. As water is a state subject therefore the Model Bill could not be adopted directly by the Central Government. Till date, no State has actually adopted it, except Gujarat and Maharashtra. The states of Andhra Pradesh, Goa, Tamil Nadu and Kerala have also enacted and implemented some groundwater legislation. In addition, lack of water pricing and tax mechanisms also pose a challenge towards effective groundwater management.

2.3.2. Economic Factors

Central Groundwater Board mentions that till date no water rates as such are being charged to farmers rather subsidized energy is provided which lowers the cost of consuming groundwater. Given the low private cost of using groundwater (cost of operating the pump) farmers do not have an incentive for using this resource at the optimal level. Instead, overuse of groundwater (and other inputs) is frequent given the expectation of higher yields (Athurkorala & Wilson, 2012, p.896).After the 1970s individual farmers began migrating towards groundwater irrigation. This development of groundwater irrigation was triggered by the subsidization of electricity, innovation of boreholes, mechanized diesel and electric pumps. Majority of the states in India have subsidized agricultural power consumption by adoption of a flat-rate tariff system (Swain & Charnoz, 2012, pp.3-4). It is pointed out that this subsidized electricity in agriculture is one of the major challenges for groundwater management. Experts believe that over pumping can be reduced by making rationing of electricity (Mukherjee et.al, 2012, pp.2-3). There is a huge debate amongst the environmental experts regarding subsidized electricity provision. Few suggest that pervasive electricity pricing has made groundwater more affordable. But, it is not necessary that increasing electricity rates may increase water tables as then the problem of electricity theft would arise. Farmers getting electricity at higher costs would earn by charging higher price from consumers. From the 1990s to 2002, the electricity subsidy to agriculture increased by a factor of 3.4. Consequently, over 40percent of the state's budget deficit is accounted for subsiding electricity (Singh, 2003). Withdrawing groundwater at rates that threaten to deplete aquifers in the affects not just the livelihood of farmers and the regional economy but also the broader economy through the significant loss of food staples currently produced in the region. Badiani and Jessoe (2011, pp.2-4) stated that free electricity was blamed for excess mining of groundwater). Their study concluded that electricity subsidies are partly driving groundwater extraction, finding that that a 10percent decrease in electricity subsidies would reduce groundwater extraction by 4.4 percent. These subsidies have led to a shift towards water intensive crops, which have contributed to the increase in groundwater extraction. In different parts of the country, a number of studies were conducted to analyze the negative impacts of electricity subsidies on groundwater and agricultural production. Their results suggest that electricity subsidies have contributed to groundwater overexploitation, increased groundwater extraction and shifted cropping patterns towards more water-intensive agricultural production, thus reducing the amount of groundwater available for future agricultural use. Empirical research shows that the flat-rate mode of pricing electricity consumption in the farm sector, which does not reflect the actual unit of consumption, creates incentive for the wasteful use of both electricity and groundwater (Kumar, Scott and Singh, 2011, p.2 ; Kumar & Singh, 2007, p.299; Palmer-Jones, 1994; Saleth, 1998, p.189). Zhu, Ringler, and Cai (2007, pp.1-2) also supported the supposition that energy prices effects groundwater extraction in India and also argued that subsidized energy for groundwater pumping is a major contributor to groundwater overdraft (Mukherjee and Biswas, 2016, p.65).Apart from this, according to Shah et.al. (2009, p.2) supply side factors which include grants or low-cost loan finance for water well construction and irrigation hardware, support for the collection and dissemination of hydrogeological knowledge on groundwater occurrence and potential, technical evolution of waterwell pumps have made groundwater a likeable resource. With these factors it has become far more difficult to manage groundwater resources.

2.3.3. Physical factors

Free access and low private cost of extracting groundwater has lead to expansion of irrigation which has further resulted into significant shifts in cropping pattern. Rice followed by wheat emerged as a major cropping sequence. This practice paid off in terms of increased production. But, this has also led to unsustainable use of water resource which has posed a threat to sustaining agriculture and food security of the country (Goyal, 2013, p.72). In this way it has added onto the groundwater crisis. Intensive agriculture dominated by paddy–wheat monoculture has led to overexploitation of natural resources in Punjab, especially groundwater (Kaur and Vatta, 2015, p.485). A shift in cropping pattern away from wheat-rice has been suggested since a long time but farmer may not move towards diversification until incentivized by economically attractive alternatives. Till then, the excess use of groundwater in paddy may be curtailed by, (1) increasing marginal cost of water through subsidy reduction, (2) reducing dependency on groundwater by promoting integrated water resources utilisation and strict monitoring (3) promoting water saving methods of paddy cultivation such system of rice intensification (SRI), direct seeded rice, etc.(Srivastava et.al., 2015, p.369). Apart from this, climate change also has a role to play in case of groundwater extraction. It has the potential to impact groundwater availability in several ways. For example, it may cause farmers to change the crops they plant or the amount of water they apply, both of which have implications for water availability. Climate change can also affect water availability directly via changes in precipitation and evapotranspiration patterns (Oehninger et.al, 2016, pp.1-2).

2.3.4. Socio-Economic Factors

In addition, groundwater depletion and degradation is affected by farmer ignorance, illiteracy and incomprehension towards its management and efficient use. Many farmers in rural areas do not have the most up-to-date information on how to grow food efficiently and economically. Groundwater can be managed or protected with the help of technology up to some extent. But, adoption of technology has both demand and supply side issues. Some of the demand side problems include ignorance by farmers, high costs and impracticality in the case of small land holdings. Improving their knowledge about techniques and technologies, providing them necessary physical resources for implementation, could dramatically increase the farmers' level of productivity (Rosegrant and Cline, 2003, pp.1917-1919). MIT institute which has designed a farmer's education programme mentions that education plays a key role in increasing productivity and sustainability by increasing local food availability, farmer income and increasing sustainability of agricultural practices. A study by Watto and Mugera on Pakistan's agriculture sector reveals that education has a relationship with water use efficiency. Statistics on education within the sample population reflect that 27percent tube well owners lack formal education while the situation is grave in case of water buyers with 43percent having no formal education. Education and extension services have positive impact (education positive but non-significant while extension positive and significant) on technical efficiency and irrigation water-use efficiency, supporting the premise that increases in human capital enables farmers to improve resource utilization and thus achieve higher efficiencies. In the literature, we find mixed results for the efficiency and education relationship, Karagiannis et al. (2003, p.66) and Soli's et al. (2009, p.214) found the impact of education significant (Watto and Mugera,2015, p.485). Illiteracy, the root cause of farmers' poor socioeconomic condition, should be tackled vigorously. Though the government is taking the initiative by adopting policies like universal education, a highly centralized bureaucracy with low accountability and inefficient use of public funds limits their impact on poverty. Farmer's awareness and education is low which also serves as a negative factor in groundwater management in rural areas. The benefits of using water protection devices, technology and less use of water harming fertilizers are not known to the farmers. Dinesh Kumar and Singh (2007) in their book mention that overall the awareness level among farmers regarding micro irrigation devices is very low. Drip irrigation is least known while sprinklers are very popular. High capital investment, low knowledge about real advantages and disadvantages of products are some of the reasons for non-adoption of these water saving technologies. Unavailability of sophisticated technology in the market, lack of experience is some of the other factors which affect water use efficiency. Apart from it, socio-economic condition of farmers affects groundwater management. Small and less resourceful agricultural water customers often struggle to adopt innovative water management practices and retrofit their existing irrigation systems. Srivastava et.al. (2015, p.3) stated that in the agriculturally developed state of Punjab, small farms were not found to be as productive and efficient (in groundwater use) as large farms. It could be because of high level of adoption of agricultural technology and mechanisation by the larger categories of farm households. Several studies have concluded that the advantages of smaller farms in terms of efficiency and productivity gains over the large farms cease to exist in agriculturally developed regions (Kazi and Toufique, 2005, p.988). Moench (2003, p.153) states that the equity impacts of groundwater development for irrigation are not positive in every aspect. Modern tube well drilling and technology tend to be capital intensive. As a result, large farmers have an advantage. Early exploiters of groundwater have typically been large farmers who produce surpluses for the market. Groundwater overexploitation is also occurring due to supply side problems viz. inadequate supply of surface or canal water for irrigation. Farmers prefer groundwater as they have better control over quantity and timing of supply (Srinivasan and Kulkarni, 2014, p.175). Jehangir et.al. (2015, p.23) mentioned in their book that to augment inadequate water supply farmers have to resort to groundwater. In the areas without canal irrigation, groundwater irrigation has expanded over the rainfed area and is based on natural recharge, which is affected by the vagaries of rainfall. Moreover, as ground water irrigation is the only form of irrigation, farmers overexploit the groundwater resource. Low groundwater recharge coupled with higher rate of withdrawal could be the reason for low irrigated land use intensity in the district where groundwater is the only form of irrigation. Despite limited scope of increasing the gross irrigated area, farmers still exploit groundwater in such areas to supplement the current water availability for higher yield. Higher agricultural productivity and population pressure are the factors behind groundwater expansion in such cases. Both canal and tank irrigation is subject to external factors of varying rainfall, and coupled with decline in the performance of canal and tank irrigation has contributed in the decline of gross irrigated area in the last decade. These factors have compelled many farmers to shift to well irrigation, while groundwater irrigation has taken over much of the rainfed areas (Bhaduri et.al., 2004, p.2).According to Shah et.al. (2009, pp.1-2) supply side measures also include grants or low-cost loan finance for water well construction and irrigation hardware, support for the collection and dissemination of hydrogeological knowledge on groundwater occurrence and potential, technical evolution of waterwell pumps have made groundwater a likeable resource. With these factors it has become far more difficult to manage groundwater resources. Groundwater can be managed or protected with the help of technology up to some extent. But, adoption of technology has both demand and supply side issues. Some of the demand side problems include ignorance by farmers, high costs and impracticality in the case of small land holdings. In India, farming practices are too haphazard and non-scientific and need some forethought before implementing any new technology. The screening of technology is important since all innovations are not relevant or attractive to all areas. It is important to screen them according to the geographical area and the local context of agriculture and let the local Kisan Vigyan Kendras (KVKs) promote it (Dwivedi, 2011, p.5).Technologies such as water-efficient indoor plumbing fixtures, closed-conduit irrigation systems like drip and micro-sprinkler systems, and computerized irrigation management techniques result in reductions in water use. Certain technical improvements at supply end can also improvise timing and lower the costs. For example, the construction of impoundment facilities permits control and regulation of runoff and allows more constant levels of supply. Over the last century, pumping technology improvements have made new sources of ground water available that previously could not be exploited because of their depth. On the other hand, failure to employ modern technology may mean lower quantities and higher costs of available supply. This coupled with supply side issue i.e. inadequate access to institutional credit at low rate of interest, disables them to invest in farm improvement.

Besides, growing marginalisation and fragmentation of land holdings, coupled with rising incidence of informal, albeit insecure tenancies and poor rural infrastructure such as road, electricity, markets and education affect factor productivity (Haque, 2006, p.68).While improvements in technology have sometimes dramatically increased the availability of water supplies, technology can also produce unwanted and unforeseen side effects. Some technology-induced or technology-influenced changes in water supply may be reversible only over time scales of thousands of years. For example, the construction of large dams, exploitation of ground water and irrigation practices may alter water quality, regional hydrology, and water-dependent ecosystems in ways that are either impossible or prohibitively expensive to reverse on any reasonable time scale. Consequently, a complete assessment, including considerations of sustainability (and intergenerational equity), of the impacts of new and existing water supply technology, the time domains over which the benefits and costs of the technology are likely to be borne etc. should be done. In addition, there is a need to improvise socio-economic status of farmers so that they may understand and apply the required water saving technology.

2.3.5. Behavioural Factors

It is widely accepted that majority of the environment related problems are due to unsustainable human activities. As new issues of environment come up, there has been a recent focus on understanding the linkage between attitudes and behaviour (Fishbein and Azjen, 1975, p.50) of people towards environment protection and conservation. Farmer's positive or negative attitudes about groundwater conservation practices can affect their behaviour about adoption of water conservation practices**.** Farmer’s behaviour is highly affected by socio-economic variables viz. size of land holding, educational level, off-farm income, and environmental values (Varua & Dave, 2017, p.141; Toogood et.al., 2003). Farmers are often characterized as having ties to the land that give them deep awareness of natural cycles, appreciation for natural beauty and a sense of stewardship, but at the same time farmers are characterized as primarily utilitarian, causing misuse of the land (Sullivan et.al,1986). Thus, farmers may both care for and pollute the land simultaneously. Farmers might be aware of environmental problems but they do not see their farming operation as a part of the problem, and thus there is no need to change anything. Traore (1998, p.4) found that neither farm size nor plans for heirs to continue farming were correlated with adoption of conservation techniques in Canada. In contrast, Featherstone and Goodwin (1993) found that large farmers in the USA with long-term plans for heirs to continue farming were more likely to invest in conservation measures than smaller ones. These conflicting results suggest that there are no simple answers to the question of how farm size and conservation are related. Several studies claim that older farmers are less willing to use land-use planning and/or change farm management practices while other studies show that younger and more educated farmers tend to be more willing to adopt new technologies and join conservation schemes. All farmers also have personal attitudes. There are several definitions of attitudes, ranging from theoretical-attitudes are readiness to act, to operational- attitudes as they are measured in attitude tests. The fruitfulness of the very concept of attitudes has been debated by scholars. Attitudes are neither permanent nor static and they are recreated each time we respond to a question, a behavior or a specific occurrence (Eagly and Chaiken, 1993, pp.1-2). Thus, to conclude that a farmer has a certain attitude when it comes to management of the farm and nature is a pure speculation. The literature shows a great diversity of attitudes and, since attitudes are not static, change even within an individual and among individuals will differ, thus generalizations are hard to make (Ahnstorm et.al., 2009, p.361).

2.4. Conclusion

Groundwater became a popular resource with its ease of accessibility and flexibility in use. While developing groundwater resource promises to help increase foodgrain production, alleviate poverty in many areas, the most formidable challenge are its sustainable use and management in regions where it is stressed. Though, there are several management mechanisms Ostrom et.al. (1998) recognize that their successful implementation is accompanied by an observation of the real-world setting. Therefore, in the light of the literature review made in this chapter, the present study elaborated upon the several factors which influence groundwater management ranging from social, political, economic, physical to other contextual factors. The sustainable management of aquifers is a burning problem in many countries. A deeper understanding of the factors becomes necessary as it would assist in providing a better solution as well as see whether the present management is sustainable. All the different governance mechanisms viz. centralisation, individualisation and community management of governing common pool resources have their own set of flaws. Thus, there exists need for developing a new hybrid approach which can use new data sources such as environmental tracers, remote sensing data, geophysical and socio-economic data. Such an approach would provide a solution as per the local setup. Finally, the natural and engineering sciences have to interface much more with economics and politics to be of real practical use.

Chapter III

Groundwater: Extent and Dynamics behind its Management

3.0. Introduction

Water has always played a central role in human societies being the key input to almost all production, in agriculture, industry and consumption activities. Achieving basic water security, harnessing the productive potential of water and limiting its destructive impacts, has been a constant struggle since the early times. Throughout history, water has also been a source of dispute and even conflict between uses as well as users. Being a common pool resource, its extraction results in externality (Saltani and Saboohi, 2008, p.1) which may ultimately cause "tragedy of commons' anytime sooner or later. Human activities involving industrial, agricultural development and the inadequate management of land and water resources have, directly or indirectly resulted in the degradation of environment viz. water and soil (Purushotam et.al., 2010, pp.1-2). Different categories of drivers are behind the processes of change in groundwater systems viz. demographic, socio-economic, science and technology, natural, political and anthropogenic (Gun, 2012; Wada, 2010, pp.3-4). As far as impacts of groundwater stress are considered they also range from environmental to socio-economic, political and health. In this chapter, we have presented an overview of both the drivers and implications of groundwater stress with particular reference to India. Water resources development and management remains to be a case in almost all developed and developing countries. The prime motive behind such efforts is the struggle for growth, sustainable development and poverty reduction. Huge investment in water development and management remain an urgent priority.

> *"Water is a blessing for human kind. It is the life blood of farming. Nations, cities and civilizations have grown near rivers. Our scriptures have praised the life giving quality of water. At the same time, having an excess of water or its complete absence can be a curse too. Last year, many parts of our country were affected by drought. Farmers were in acute distress. This year, we are having a deluge of water, leading to flash floods and consequent destruction and loss of valuable property in many States of the Union. Once again, farmers in these parts are in distress. In a way, these two phenomena demonstrate the vulnerability of our people to the vagaries of nature. They also demonstrate the importance that irrigation can play in mitigating the risk arising out of fluctuating rainfall – both when it is in shortage and when it is in excess. Irrigation can ensure that people's suffering from water related disasters is minimized and that they enjoy the benefit of nature's bounty".*
>
> -Excerpts from speech of Dr. Manmohan Singh at the Inauguration of the National Conference of Irrigation and Water Resources Ministers, November 30, 2005

There are primarily two objectives of this chapter. Firstly, to understand the availability, accessibility and stage of groundwater development in India, particularly in Uttar Pradesh. Secondly, to explore the linkage between few socio-economic factors and groundwater development. Therefore, using various secondary data from Central and State Ground Water Boards, Census 2011, Ministry of Agriculture, 3rd, 4th and 5th Minor Irrigation Census Reports, Planning Commission Reports on groundwater resources availability, utilization and stage of development**,** total population, population below poverty line in rural India, electricity consumption by agriculture sector, number of electric and diesel pumpsets, average power tariff rate of agricultural consumers, power subsidies, environmental performance scores. Due to data availability constraints, the time period for all the variables is not same. Though, an effort has been made to maintain consistency. Data analysis has been done using descriptive statistics and simple regression.

The chapter has been divided into two sections. The first section captures introduction, objectives, methodology, data and literature on water especially groundwater availability, utilisation and stage of development at macro (state wise) and at micro level with reference to Uttar Pradesh. The second section presents a brief literature review and data analysis on factors affecting groundwater use and management in agriculture sector.

3.1. Groundwater Resources in India

Focusing on the water resource base of India, data suggests that it has only 4 percent of the water resources catering to 1.25 billion population. The table 3.1 shows that 17.1 percent of world population survives on 1508 m^3 of water per day, which is far below than the world average. With rising scarcity it is estimated that per capita water availability in India would further decline.

Table 3.1: Water Facts: India

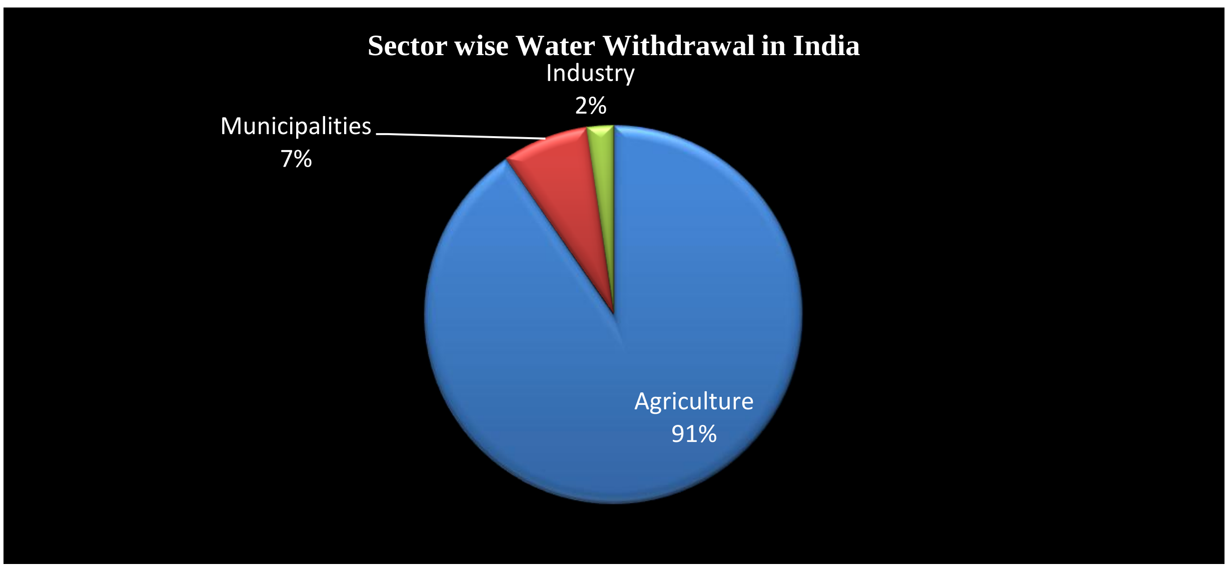
Area of the country as % of World Area	**2.4 percent**
Average annual rainfall	**1160 mm (world average 1110 mm)**
Per capita water availability	**1508 m^3**
Population as % of World Population	**17.1 percent**
Rank in per capita availability	**132**
Rank in water quality	**122**

Water as % of World Water	**4%** **Surface water – 690 km^3(17.3 percent)** **Replenishable Groundwater – 433 km (10.8 percent)**

Source-Ministry of Jal Shakti (2019), Water Resources Information System, Central Water Commission, GOI, India

Focusing on sector-wise use of water in India, data and literature shows that agriculture (91 percent) is the primal user followed by domestic use (7 percent) and industry (2 percent) respectively.

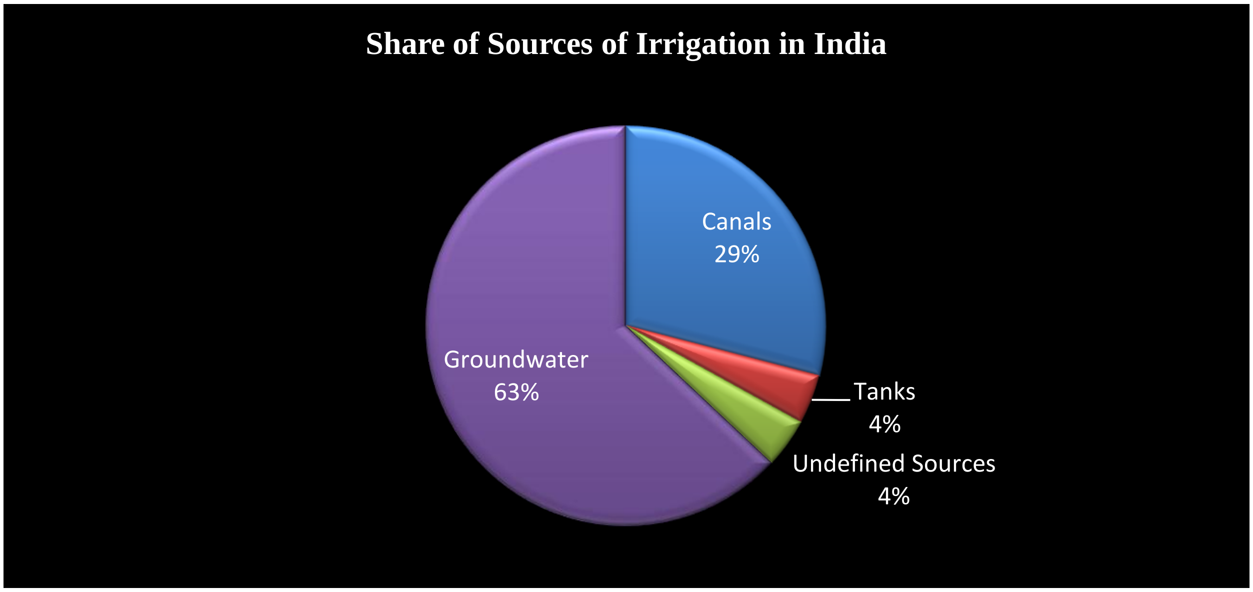
Fig.2: Sector Wise Water Withdrawal in India



Source- United Nations (2019), Water Database-India, AQUASTAT, Food and Agricultural Organisation.

Considering agriculture, data (Fig.3) reflects that groundwater share in irrigation is the highest (63 percent) and this share has grown gradually. Groundwater has rapidly emerged to occupy a dominant place in India's agriculture and food security. It has become the main source of irrigation and it now accounts for over 60 percent of irrigated area.

Fig.3: Source of Irrigation Water on Area Equipped for Full Control Irrigation in India



Source-United Nations (2019), Water Database-India, AQUASTAT, Food and Agricultural Organisation

The dynamic ground water resources are also known as Annual Replenishable Ground Water Resources since it gets replenished/ recharged every year. The Annual Replenishable Ground Water Resource for the entire country has been assessed as 433 billion cubic meter (bcm) as per 2017. The major source of ground water recharge is the monsoon rainfall. About 58% of the annual replenishable resources i.e. 253 bcm are contributed by monsoon rainfall recharge. The overall contribution of rainfall to country's Annual Replenishable Ground Water Resource is 68% and the share of other sources viz. canal seepage, return flow from irrigation, recharge from tanks, ponds, and water conservations structures taken together is 32%. Regional analysis of Ground Water Resources of India as on March, 2011 given in table 3.2 below show that North western plain states and Western Arid region have highest groundwater development[1] as well as have the highest share of over-exploited units. This shows the grave stress level in the region and the alarm for crisis.

[1]The stage of ground water development is a ratio of Annual Ground Water Draft and Net Annual Ground Water Availability in percentage. A higher percentage indicates high groundwater abstraction and low recharge.

Table 3.2: Region wise Classification of Ground Water Resources Availability and Status of its Utilization in India

Regions	Annual Rep.GW (in bcm)	Natural Discharge (in bcm)	Net Annual GW Availability (in bcm)	Annual GW Draft (in bcm)	Stage of GW Dev (in percent)	Categorization of Assessment Units		
						Total Units (no.)	Over-Exploited (no.)	Critical (no.)
Northern Himalayan States	5.4	0.48	4.92	1.84	37	30	2 6.67*	0
North Eastern Hilly States	33.99	3.02	30.98	5.63	18	118	0 *0.00**	0
Eastern Plain States	111.63	9.03	102.5	43.97	43	1895	1 *0.05**	2 *0.11**
North Western Plain States	80.78	6.92	73.85	72.17	98	277	201 *72.56**	28 *10.1**
Western arid Region	27.38	1.97	25.4	24.48	96	462	172 *37.23**	62 *13.4**
Central Plateau States	90.723	5.19	85.53	36.11	42	985	31 *3.15**	6 *0.61**
Southern Peninsular States	82.78	7.14	75.65	46.4	61	1946	432 *22.20**	128 *6.58**
Islands	0.34	0.01	0.32	0.01	4	10	0	0
Total	**433.02**	**33.77**	**399.26**	**230.63**	**58**	**5723**	**839**	**226**

Source- Jha (2013**)**
Note-* denotes percentage

As per the CGWB assessment (2017) wherein they took total of 5723 assessment units in the country, ground water development was found to exceed more than 100 % of the natural replenishment in 839 units (14.7 %) which have been categorized as 'Over-exploited'. Ground water development was found to be to the extent of 90 to 100 percent of the utilizable resources in 226 assessment units (3.9 %), which have been categorized as 'Critical'. 550 assessment units with stage of ground water development in the range of 70 to 100 % and long-term decline of water levels either during pre- or post-monsoon period have been categorized as 'Semi-Critical' and 4078 assessment units with stage of ground water development below 70% have been categorized as 'Safe. Macro level picture of groundwater availability (GW Avail), utilization

(Ground Water use in Irrigation and other Sector) and development has been presented in the table 3.3 taking data from 2005 to 2017.

The table 3.3 reflects that 14 States comprise 91 percent of ground water potential. Among the states, Uttar Pradesh ranks first in terms of share of replenishable ground water resources followed by Maharashtra, Madhya Pradesh, Andhra Pradesh, West Bengal and Assam. CGWB classified the country into safe, semi critical and over exploited ground water resources. The overall stage of ground water development in the country is 63 percent (it has risen with period, was 58 percent in 2005 became 61 percent in the year 2011). Although all the states have been consuming groundwater at significant levels, in some regions the groundwater development is extremely high (more than 100 percent) which signifies that the rate of use is higher than annual replenishment rate. Delhi, Haryana, Punjab and Rajasthan have >100 percent groundwater development while Gujarat, Uttar Pradesh, Karnataka and Tamil Nadu have >70 percent groundwater development. In rest of the states / UTs the stage of ground water development is below 70%.

Table 3.3: State-wise Groundwater Availability, Utilization and Development

S. No	States	2005 GW Avail	2005 Irrigation	2005 Other	2005 Total	2005 GW Dev. (%)	2011 Gw Avail	2011 Irrigation	2011 Others	2011 Total	2011 Gw Dev (%)	2017 Gw Avail	2017 Irrigation	2017 Others	2017 Total	2017 Gw Dev (%)
1	Andhra Pradesh	32.95	13.88	1.02	14.9	45	32.57	13.18	1.33	14.51	45	20.15	7.85	1.05	8.9	44.15
2	Arunachal Pradesh	2.3	0.0008	0	0.0008	0.04	4.06	0.002	0.001	0.003	0.08	2.67	0	0.01	0.01	0.28
3	Assam	24.89	4.85	0.59	5.44	22	25.79	2.86	0.64	3.49	14	24.26	1.97	0.76	2.73	11.25
4	Bihar	27.42	9.39	1.37	10.77	39	26.86	10.25	1.7	11.95	44	28.99	10.78	2.48	13.26	45.76
5	Chattisgarh	13.68	2.31	0.48	2.8	20	11.63	3.43	0.62	4.05	35	10.57	3.98	0.72	4.7	44.43
6	Delhi	0.28	0.2	0.28	0.48	170	0.29	0.14	0.25	0.39	137	0.3	0.09	0.27	0.36	119.61
7	Goa	0.27	0.04	0.03	0.07	27	0.145	0.01	0.03	0.04	28	0.16	0.02	0.03	0.05	33.5
8	Gujarat	15.02	10.49	0.99	11.49	76	17.59	10.75	1.11	11.86	67	21.25	12.84	0.74	13.58	63.89
9	Haryana	8.63	9.1	0.35	9.45	109	9.79	12.35	0.71	13.06	133	9.13	11.53	0.97	12.5	136.91
10	Himachal Pradesh	0.39	0.09	0.02	0.12	30	0.53	0.25	0.13	0.38	71	0.46	0.2	0.19	0.39	86.37
11	Jammu & Kashmir	2.43	0.1	0.24	0.33	14	3.83	0.2	0.61	0.81	21	2.6	0.2	0.56	0.76	29.47
12	Jharkhand	5.25	0.7	0.38	1.09	21	5.76	1.31	0.55	1.86	32	5.69	0.8	0.78	1.58	27.73
13	Karnataka	15.3	9.75	0.97	10.71	70	14.81	8.59	0.82	9.41	64	14.79	9.39	0.95	10.34	69.87
14	Kerala	6.23	1.82	1.1	2.92	47	6.07	1.3	1.53	2.84	47	5.21	1.22	1.45	2.67	51.27
15	Madhya Pradesh	35.33	16.08	1.04	17.12	48	33.29	17.48	1.35	18.83	57	34.47	17.43	1.45	18.88	54.76
16	Maharashtra	31.21	14.24	0.85	15.09	48	32.15	16.15	1.03	17.18	53	29.9	15.1	1.23	16.33	54.62
17	Manipur	0.34	0.002	0.0005	0.002	0.65	0.4	0.0033	0	0.004	1.02	0.39	0	0.01	0.01	1.44
18	Meghalaya	1.04	0	0.002	0.002	0.18	1.6	0.0015	0	0.0017	0.08	1.64	0.03	0.01	0.04	2.28
19	Mizoram	0.04	0	0.0004	0.0004	0.9	0.027	0	0.001	0.001	3.52	0.19	0	0.01	0.01	3.82
20	Nagaland	0.32	0	0.009	0.009	3	0.55	0	0.03	0.03	6.13	1.98	0	0.02	0.02	0.99
21	Orissa	21.01	3.01	0.84	3.85	18	16.69	3.81	0.92	4.73	28	15.57	5.28	1.29	6.57	42.18
22	Punjab	21.44	30.34	0.83	31.16	145	20.32	34.17	0.71	34.88	172	21.58	34.56	1.22	35.78	165.77
23	Rajasthan	10.38	11.6	1.39	12.99	125	10.83	13.13	1.71	14.84	137	11.99	14.85	1.92	16.77	139.88
24	Sikkim	0.08	0	0.01	0.01	16	0.044	0.003	0.009	0.011	26	1.52	0	0	0	0.06
25	Tamil Nadu	20.76	16.77	0.88	17.65	85	19.38	13.17	1.76	14.93	77	18.2	13.06	1.67	14.73	80.94
26	Telangna	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	12.37	7.09	1	8.09	65.45
27	Tripura	1.97	0.08	0.09	0.17	9	2.358	0.093	0.069	0.163	7	1.24	0.02	0.08	0.1	7.88
28	Uttar Pradesh	70.18	45.36	3.42	48.78	70	71.66	48.74	4.04	52.78	74	65.32	40.89	4.95	45.84	70.18
29	Uttaranchal	2.1	1.34	0.05	1.39	66	2	1.1	0.03	1.13	57	2.89	1.3	0.34	1.64	56.83
30	West Bengal	27.46	10.84	81	11.65	42	26.58	9.72	0.97	10.69	40	26.56	10.84	1	11.84	44.6
	Total States	398.7	212.38	18.04	230.44	58	397.6	222.21	22.66	244.86	62	392.04	221.33	27.14	248.47	63.38

Source-Ministry of Jal Shakti (2005-2017), Ground Water Year Books, Central Ground Water Board, GOI, India

Focusing on the state which has the highest groundwater availability and is the largest consumer of groundwater in irrigation sector viz. Uttar Pradesh, an in-depth data assessment and literature review has been done in this chapter.

3.2. Hydrogeological Profile of Uttar Pradesh

The state has more than 32 large and small rivers, of them, the Ganges, Yamuna, Saraswati, Sarayu, Betwa and Ghaghara are larger rivers of the state.

Surface water: Major source of surface water in the state are rivers flowing from southeast to southwest direction. Major rivers include Ganges, Yamuna, Ghagra, Gomti, Gandak, Sone and Sarda. The Ganges being too large to be tamed, no major irrigation projects have been created on its mainstream. The irrigation needs are being met by canal projects constructed early this century. In recent years, some of the northern and southern tributaries of Ganges and their minor feeder streams have been tamed, creating a few reservoirs (CGWB, 2015 p.4).

Groundwater: The state has huge amount of groundwater but its use is unsustainable in almost all parts. The annual replenishable groundwater resource in Uttar Pradesh is 77.19 bcm, net annual groundwater availability is 71.66 bcm, annual groundwater draft is 52.78 bcm and the stage of groundwater development is 74 percent as per 2015. The total number of over exploited[2] blocks in the state is 111, 68 blocks are critical[3] while 82 blocks fall in semi critical[4] category. Data evidences show that groundwater stress has deepened over the years in Uttar Pradesh. Table 3.4 reflects that wherein the percentage of over exploited blocks was 0.24 in year 2000 it has reached to 13.53 percent in 2011. The number of critical blocks has also increased from 20 in 2000 to 68 in the year 2011. As per the latest available data showcasing the number of blocks in different categories of groundwater blocks reveal that the situation has not changed much between 2011 and 2013. The percentage of over-exploited blocks in Uttar Pradesh is 13.78 percent while 12.7 percent fall under critical and semi-critical category. Though, a large proportion is still in safe[5] category i.e. 75.53 percent, but a matter of concern is that the number

[2] Over exploited block refers to the geographical location or block where groundwater development is more than 100 percent.

[3] Critical refers to the area where groundwater development is more than 90 percent but less than 100 percent.

[4] It refers to the area wherin groundwater development is more than 70 percent but less than 90 percent.

[5] Safe category blocks are those where groundwater development is less than 70 percent.

of blocks in this category has decelerated over the years as in year 2000, 745 blocks out of 820 were safe.

Table 3.4: Number of Over-Exploited, Critical, Semi-Critical and Safe Blocks In Uttar Pradesh

Category of Blocks	Year-2000	Year-2004	Year-2009	Year-2011	Year-2013
Over Exploited	2 (0.24)	37 (4.51)	76 (9.26)	111 (13.53)	113 (13.78)
Critical	20 (2.43)	13 (1.56)	32 (3.90)	68 (8.29)	59 (7.19)
Semi Critical	53 (6.46)	88 (10.73)	107 (13.04)	82 (10.00)	45 (5.48)
Safe	745 (90.85)	682 (83.17)	605 (73.78)	559 (68.17)	603 (73.53)
Total	**820**	**820**	**820**	**820**	**820**

Source- Ministry of Jal Shakti (2000-2013), Department of Groundwater, GOUP, Uttar Pradesh, Lucknow.
Note- Figures in brackets are in percentage terms

Table 3.5 shows region wise dynamic groundwater resource use, availability and development of Uttar Pradesh. Data depicts that Western Region has the highest level of groundwater development with an average of all districts being 84.77 percent followed by Central 72 percent, Eastern (70.70 percent) and Bundelkhand (65.14 percent). As far as groundwater availability is concerned, it is highest in the central region (which is also the biggest user of groundwater in irrigation sector) followed by Eastern, Western and Bundelkhand. The issue of concern over here is that Western region leads in groundwater development though neither does it have the highest availability nor it share is relatively higher in irrigation sector.

Table 3.5: Region Wise Groundwater Availability, Utilisation and Stage of Groundwater Development in Uttar Pradesh (in ham)

Regions	GW Availability	Irrigation	Domestic and Other	Total	GW Dev (in %)
Western Region	88003.73	68038.31	4263.11	72301.65	84.77
Central Region	150994.6	98504.4	6722.6	105226.9	72.00
Eastern Region	97066.7	60952.89	6962.29	67915.26	70.70
Bundelkhand Region	65040.43	29794.57	2951.42	32745.71	65.14

Source- Ministry of Jal Shakti (2015), District Groundwater Brochure, Central Ground Water Board, GOI, India.

MOEF (2015), Environmental Information System Report, GOUP, mentions that the maximum withdrawal (ground water draft) is from the western region covering 30 districts i.e. 2.15 mham while minimum withdrawal is from Bundelkhand region i.e. 0.23 mham. Studies reveal that 659 blocks are affected with ground water level decline. Overall, as per 2011 data, 179 blocks from 43 districts have been are categorised as stressed (Over-exploited/Critical) in Uttar Pradesh fall in Western region of the state. An article published in Hindustan Times (April, 22, 2016,p.2) by Peeyush Khandelwal throws light on the groundwater level in several districts of western Uttar Pradesh. The report mentions that groundwater level has declined constantly over the past decade. Figures obtained from the Central Ground Water Board (CGWB) through an RTI reply filed by an activist show a decline in Ghaziabad, Gautam Budh Nagar, Baghpat and Meerut districts.In Ghaziabad's Razapur block, water level went from 16.95 metres below ground level (mbgl) in January 2006 to 20.21 mbgl in January 2010. The RTI replies did not provide data for the remaining areas in the district. According to Ghaziabad municipal corporation officials, the current average water level in the city is estimated at around 140 feet (nearly 42.672 metres) and levels are going down by five feet (nearly 1.524 metres) annually."The situation has reached alarming levels. There is hardly any recharge while water extraction is rampant. We cannot regulate it (water extraction) since we do not have by-laws through which we can act. Staff shortage, even for maintenance, is also a major issue," said RK Yadav, the corporation's executive engineer, water works. Environmental activists cite that there is mass violation of water extraction by developers, water mafia and others. Officials too show a lackluster attitude towards water conservation issues. Water recharging pits and rainwater harvesting units are lying defunct at most places, but are shown functioning on papers. Bose (2017,p.2) in his study on Baghpat district mentioned that environmentally unsustainable agricultural practices the use of hybrid seeds, indiscriminate use of chemicals as fertilizers and pesticides along with high levels of water consumption in the region have led to excessive groundwater withdrawals. The water scarcity has become grave and lead to restoration efforts. Table 3.6 shows that the stage of groundwater development is highest in Pratapgarh (144 percent) followed by Saharanpur (133 percent), Firozabad (117 percent), Agra (114 percent), Rampur (107 percent), Ghaziabad (105 percent), Kasganj (100 percent) and Baghpat (98 percent) etc. Overall, it is clear from the data western region has more number of districts which has groundwater development more than 100 percent.

Table 3.6: District Wise Groundwater Availability, Utilization and Development in Uttar Pradesh (in ham) as of 2015

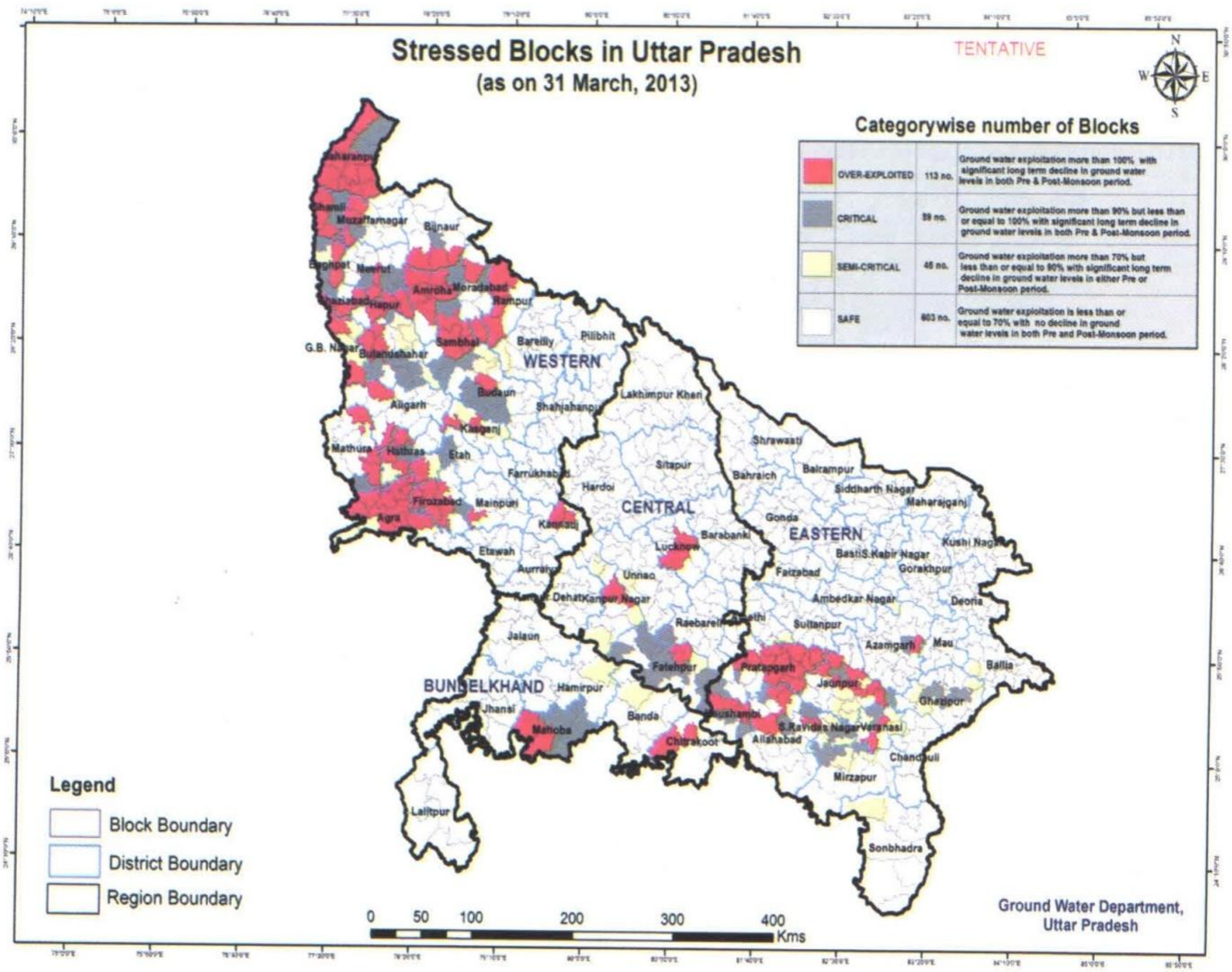
	S. N0.	District	GW Avail	Use in Irrigation	Use in Domestic & Other	Total	Irrigation -Future	other uses 2025	GW Dev (in %)
Western	1	**Agra**	82214	87858	5693	93551	5192	9317	114
	2	**Aligarh**	86808	65379	5920	71299	12409	9842	82
	3	**Auriya**	64242	41471	2777	44249	18817	3954	69
	4	**Bareilly**	174396	97066	6785	103851	66853	10476	60
	5	**Baghpat**	45369	42401	2199	44600	934	3598	98
	6	**Bijnor**	137519	87228	5524	92752	45971	9402	67
	7	**Budaun**	111378	88593	5799	94392	17042	8359	85
	8	**Bulandshar**	151866	118443	5953	124396	26314	8403	82
	9	**Etah**	64198	53131	3550	56682	6878	5638	88
	10	**Etawah**	73924	31472	2522	33995	39175	3276	46
	11	**Farukhabad**	61894	46022	3394	49417	10647	5225	80
	12	**Firozabad**	73046	81486	4055	85541	5266	7144	117
	13	**Hathras**	57482	45783	2802	48585	10278	3871	85
	14	**Mathura**	104812	92384	4003	96387	22239	6190	92
	15	**Meerut**	115160	77433	3381	80814	33560	4636	70
	16	**Moradabad**	82697	65493	4668	70161	13956	7744	85
	17	**Pilibhit**	123930	76128	3846	79974	41768	6034	65
	18	**Rampur**	70056	70689	4014	74703	7053	7026	107
	19	**Muzaffarnagar**	98139	60527	4718	65246	36019	7644	66
	20	**Saharanpur**	133081	171402	5523	176925	0	8804	133
	21	**Shahjahnpur**	137267	76348	5268	81616	53147	7772	59
	22	**G.B.Nagar**	45820	39872	2772	42644	3944	3134	93
	23	**Kannauj**	64654	39804	3238	43042	24210	4635	67
	24	**Gaziabad**	30016	24457	7109	31567	2452	12456	105
	25	**Hapur**	40039	32979	2670	35649	5045	3645	89
	26	**Kasganj**	58090	55147	2658	57805	4026	4206	100
		Average	**88003.73**	**68038.31**	**4263.11**	**72301.65**	**19738.27**	**6631.96**	**84.76**
Eastern	1	**Allahabad**	117531	83812	11320	95132	21956	15587	81
	2	**Azamgarh**	132861	73309	13186	86495	37525	23148	65
	3	**Ambedkar Nagar**	102989	53578	5016	58595	41479	7932	57
	4	**Ballia**	88953	52184	6739	58924	26062	10707	66
	5	**Balrampur**	84891	38075	4219	42294	41232	5583	50
	6	**Bahraich**	107549	52440	6798	59238	42159	12951	55
	7	**Basti.**	101044	74544	4831	79375	19209	7291	79
	8	**Deoria**	101175	71517	7505	79022	19652	10006	78
	9	**Faizabad**	72700	41401	3810	45211	26568	4731	62
	10	**Ghazipur**	125085	77844	7770	85615	34970	12708	68

	11	**Gonda**	117028	75828	6834	82662	31618	9582	71
	12	**Gorakhpur**	176256	88964	7181	96145	73632	13661	55
	13	**Jaunpur**	124306	101176	9427	110604	14904	15990	89
	14	**Kushi Nagar**	166495	71076	7644	78720	81120	14300	47
	15	**Kaushambhi**	49945	42184	3298	45482	6575	5051	91
	16	**Maunath Bhanjan**	48296	29635	4125	33759	11372	7289	70
	17	**Maharajganj**	112163	63577	5760	69337	38516	10069	62
	18	**Mirzapur**	57819	30919	5150	36070	16889	10388	62
	19	**Pratapgarh**	115645	128377	34556	162933	28204	44922	141
	20	**Siddhrth Nagar**	145272	87581	5727	93308	47705	9986	64
	21	**Sonbhadra**	21106	7620	1480	9100	6780	6706	43
	22	**Shrawasti**	42110	27376	2239	29615	10419	4315	70
	23	**Siddhrth Nagar**	145272	87581	5727	93308	47705	9986	64
	24	**S. Ravidas Nagar**	39972	33608	3373	36980	473	6390	93
	25	**S. Kabeer Nagar**	71202	44391	3377	47768	21183	5628	67
	26	**Sultanpur**	104541	70793	5300	76092	24526	9222	73
	27	**Varanasi**	48595	36338	5590	41928	3402	11852	86
		Average	**97066.7**	**60952.89**	**6962.29**	**67915.26**	**28734.63**	**11332.6**	**70.70**
Central	1	**Barabanki**	207632	126319	7211	133529	70599	10714	64
	2	**Fatehpur**	111528	100681	5500	106181	4085	9581	95
	3	**Hardoi**	181375	116701	7579	124280	52767	11907	69
	4	**Lakhimpur Kheri**	284590	169197	8240	177437	100160	15233	62
	5	**Kanpur Nagar**	78787	56225	10375	66601	0	24734	85
	6	**Kanpur Dehat**	86885	55181	3793	58974	26139	5565	68
	7	**Lucknow**	64315	39879	4232	44110	16062	8375	69
	8	**Raebarely**	85359	57189	4943	62132	19857	8313	73
	9	**Sitapur**	234032	155285	9190	164475	64580	14167	70
	10	**Unnao**	175443	108387	6163	114550	57054	10001	65
		Average	**150994.6**	**98504.4**	**6722.6**	**105226.9**	**41130.3**	**11859**	**72**
Bundelkhand	1	**Banda**	67546	34094	2804	36898	29526	3926	55
	2	**Chitrakoot**	24495	14043	2155	16197	7586	4206	66
	3	**Hamirpur**	51535	30091	2952	33042	16732	4944	64
	4	**Jhansi**	61296	37904	3802	41706	19012	4380	68
	5	**Jalaun**	185119	48576	4395	52971	130211	6333	29
	6	**Lalitpur**	49124	27215	3056	30271	18397	3512	62
	7	**Mahoba**	16168	16639	1496	18135	23	2675	112
		Average	**65040.43**	**29794.57**	**2951.429**	**32745.71**	**31641**	**4282.28**	**65.14**

Source- Source- Ministry of Jal Shakti (2015), Ground Water Year Book-Uttar Pradesh, Central Ground Water Board, GOI, India.

Taking a glance at the map provided by Groundwater Department, Uttar Pradesh on groundwater stressed blocks in the country it is seen that western region is the worst sufferer wherein majority of the over-exploited districts lie. Ruthless deforestation, cropping pattern, systematic neglect of local water systems, excessive use of fertilizers and tractors, have made sub-soil less porous leading to less water percolation through soil (South Asia Network on Dams, Rivers and People 2016,p.5).

Fig.4- Groundwater Stressed Blocks in Uttar Pradesh



Source-Department of Groundwater (2013), GOUP, Uttar Pradesh, Lucknow

Further, in order to check which region has precarious problem of groundwater, an analysis of depth of water level / table (as shown in table 3.7) has been done which reflects that western region leads with an annual average of 9.97m bgl, Bundelkhand has 7.74m while Central and Eastern region have 7.34m and 6.00m respectively.

Table 3.7: Region wise Depth (in metre) to water level in Uttar Pradesh (as of 2015)

Regions	May(14)	Aug(14)	Nov(14)	Jan(15)	Annual
Western Region	9.86	9.59	10.25	10.17	9.97
Eastern Region	5.78	4.82	5.94	6.88	6
Central Region	7.56	6.88	7.3	7.6	7.34
Bundelkhand Region	7.73	7.26	7.62	8.35	7.74

Source- Ministry of Jal Shakti (2015-16), Groundwater Year Book, Central Ground Water Board, GOI, India.

Micro assessment of the water depth levels have been presented in Table 3.8 so as to see which region and which districts have grave water related issues. The table reveals that in Western region, Baghpat (21.69) has the lowest water table followed by Agra(18.51), Gautam Budhh Nagar(16. 39), Etawah (14.46) and so on. In Eastern region, Kaushambi (14. 77) has the lowest depth followed by Jyotiba Phule Nagar (11) and Shrasvasti (9.06). Lucknow and Kanpur Dehat have low water tables in central regions while in Bundelkhand, Chitrakoot and Jalaun have depth of 12.19m and 8.99m respectively. Thus, the overall picture depicts that Western region districts are suffering the most and Baghpat being an area of concern.

Table 3.8: District wise Depth (in metre) to water level in Uttar Pradesh (as of 2015)

Districts	May	Aug	Nov	Jan	Annual Average
Agra	18.47	17.77	18.86	18.96	18.51
Aligarh	4.97	5.31	5.94	5.34	5.39
Auraiya	8.06	7.82	8.03	8.56	8.12
Bareilly	6.2	5.5	6.01	6.22	5.98
Baghpat	22.58	22.07	19.05	23.05	21.69
Bijnor	8.57	8.4	8.94	8.94	8.81
Badaun	9.84	10.23	10.94	10.93	10.49
Bulandshahar	7.37	6.48	7.84	8.27	7.49
Etah	7.27	6.8	6.89	7.09	7.01
Etawah	14.39	12.95	15.19	15.3	14.46
Farukkhabad	11.46	9.9	11.96	12.24	11.39
Firozabad	9.64	9.49	9.51	10.06	9.67
Hathras	9.73	8.96	9.52	8.14	9.09
Mathura	6.02	5.08	5.63	6.42	5.79
Meerut	10.6	11.41	11.04	9.81	10.72

Moradabad	10.84	10.5	11.26	10.16	8.06
Pilibhit	4.22	3.27	4.08	3.86	3.86
Rampur	5.07	5.5	7.78	7.13	6.66
Muzzafarnagar	13.37	10.27	11.48	11.15	11.57
Saharanpur	10.2	9.09	9.44	8.38	9.28
Shahjahanpur	5.64	5.47	5.26	5.06	5.36
G.B.Nagar	12.25	16.72	18.4	18.2	16.39
Kannauj	9.43	10.93	12.29	10.53	10.8
Ghaziabad	10.47	10.26	10.54	10.26	10.38
WESTERN	**9.86**	**9.59**	**10.25**	**10.17**	**9.97**
Allahabad	7.21	6.02	6.87	9.27	7.34
Azamgarh	5.7	5.02	5.49	9.17	6.35
Ambedkar Nagar	5.76	4.63	5.71	6.55	5.66
Ballia	5.88	4.11	4.84	7.44	5.57
Balrampur	4.26	3.1	4.28	4.56	4.05
Bahraich	4.47	3.63	3.62	4.11	3.96
Basti	3.97	2.73	3.59	4.34	3.66
Chandauli		3.32	4.36	5.05	4.24
Deoria	3.99	3.64	4.07	5.1	4.2
Faizabad	5.64	4.76	4.86	4.76	5
Ghazipur	7.99	6.23	6.78	8.45	7.36
Gonda	4.13	3.4	4.12	5.11	4.19
Gorakhpur	4.1	4.12	4.82	5.74	4.69
Jaunpur	5.69	5.11	6.69	6.92	6.1
Jyotiba Phule Nagar	11.91	NA	12.07	11.75	11.91
Kaushambi	14.15	14.69	14.85	15.4	14.77
Kushinagar	3.26	1.83	2.73	4.14	2.99
Maharajganj	3.47	2	3.67	4.64	3.44
Mainpuri	4.52	2.79	3.11	4.43	3.71
Mau	6.09	5.06	5.76	6.24	5.78
Mirzapur	NA	6.76	8.65	9.51	8.31
Pratapgarh	7.29	6.74	7.73	7.95	7.43
Sant Kabir Nagar	4.02	3.28	4.36	4.89	4.14
Sant Ravidas Nagar	NA	7.86	8.99	10.25	9.03
Shravasti	4.56	3.64	3.69	4.6	4.12
Siddhartnagar	3.88	1.56	3.22	4.18	3.21
Sonabhadra	NA	5.55	7.3	9.67	7.51
Sultanpur	6.69	5.25	5.12	6.94	6
Varanasi	NA	8.22	11.02	8.32	9.19
EASTERN	**5.78**	**4.82**	**5.94**	**6.88**	**6**
Barabanki	5.17	4.87	5.58	5.95	5.39

Fatehpur	9.85	9.54	10.06	8.98	9.61
Hardoi	6.06	4.7	5.38	6.25	5.6
Kheri	5.08	3.46	4.65	4.64	4.46
Kanpur Dehat	9.36	9.78	8.18	8.69	9
Kanpur Nagar	10.68	10.11	9.91	11.91	10.65
Lucknow	13.16	12.26	13.32	13.05	12.95
Raebareilly	4.39	3.72	4.58	5.33	4.51
Sitapur	6.24	5.16	5.57	5.74	5.68
Unnao	5.64	5.17	5.81	5.46	5.52
CENTRAL	**7.56**	**6.88**	**7.3**	**7.6**	**7.34**
Banda	7	6.22	6.54	5.91	6.42
Chitrakoot	11.79	11.38	11.45	14.15	12.19
Hamirpur	9.64	8.97	9.09	9.66	9.34
Jhansi	6.22	5.88	6.64	7.26	6.5
Jalaun	9.06	8.51	9.68	8.72	8.99
Lalitpur	5.06	5.21	5.85	6.73	5.71
Mahoba	5.34	4.63	4.08	6	5.01
BUNDELKHAND	**7.73**	**7.26**	**7.62**	**8.35**	**7.74**

Source- Ministry of Jal Shakti (2015-16), Groundwater Year Book-Uttar Pradesh, Central Ground Water Board, GOI, India

Note: NA denotes not available

Section II

3.3. Factors influencing Groundwater Use and its Management in Agriculture Sector

3.3.1 Population Pressure

Focusing on the population growth rate and its linkage with environmental degradation (in this case groundwater development) a simple regression analysis is performed using stage of groundwater development as a dependent variable and total population as an independent variable.

$$\text{Groundwater Development} = -129.44 + (12.04)\ \text{Population} + e_i$$

The regression equation represent that groundwater development would increase by 12.04 units when there is a unit increase in population. A positive and statistically significant relationship is seen between the two variables. The R-squared value is 0.19 and the t-value is 2.54. The global population is expanding by 80 million people annually, increasing the demand for freshwater by about 64 billion. As the population grows, and the economies will continue to develop, it is likely that groundwater will be increasingly used for industry and agriculture (Lutz, 2010, pp.26-27). As per the estimates (FAO, 2015, p.39) water withdrawals have tripled over the last 50 years due to population growth. Nations around the world have been overpumping their aquifers. While most are replenishable, some of them are not particularly in many of the most populous regions. Many nations overpumping their water resources concurrently could lead to the simultaneous depletion of aquifers, and in turn, agriculture cutbacks. Thus, the world's current water scarcity could soon lead to a devastating food scarcity. Since producing grain requires large quantities of water, countries have started to cut back on their own grain production and began to import. Thus, the global water market is nearly synonymous with the international grain market. The situation has become so extreme that several of the largest cities worldwide including Los Angeles, Cairo, and New Delhi can only increase their water consumption by reducing agricultural water use. Nearly every country in the Middle East and North Africa is approaching its water limit, turning the region into the world's fastest growing grain import market (Population Institute, 2010.p.6).A study on the impact of population on groundwater availability in United States mentioned that population centers that were traditionally under high water stress due to large water use were predicted to experience even more water stress with further population growth (Sun et.al., 2012, pp.602-603). Therefore, a direct linkage is seen between population growth and groundwater stress. A similar study undertaken to assess impact of population growth on groundwater quality in a region of Sri-Lanka concluded that population growth will result in further increase of population density in the area and will produce more land use exploitation for both septic systems and agriculture (Jayasekera et.al., 2006, pp.5-6). The population growth and land use exploitation will increase the demand for groundwater for urban use and irrigation while further deteriorating water quality. Existence of such condition over a long time period is not sustainable and ultimately will deplete the quality and quantity of groundwater.

3.3.2. Land ownership pattern

Fragmentation of cultivable land into small landholdings is a serious concern. Demographic pressure, family divisions, selling of land and lack of earnest land reforms (Posani, 2009, p.3). Land accessibility has its link with rural poverty, agriculture productivity, growth, household security, natural resource usage and several other aspects. Working in this context, we have attempted to measure land distribution inequality within various land size groups (marginal, small, medium and large) in all states of India. Using data from Agriculture census 2015-16, 2010-11, 2005-06 and 2000-01 on number of operational holdings and area operated by farmers in all land size category an assessment of differences has been made. Appendices, Table 3.9.1A and 3.9.2A shows the category wise landholding patterns in each state. Percentage of various marginal, small, medium and large class landowners on national level depicts that number of marginal landholders is highest and their number has risen from year 2000 to 2016. Almost 11 percent rise has been registered during this period. The highly skewed nature of size-distribution of ownership holdings has by and large, remained unchanged over time. The size distribution of ownership holdings in India is characterised by predominance of marginal holders. The marginal holdings (less than or equal to 1 ha) constituted about 68 percent of total landholdings but owned only 24 percent of total area. The small land-size category's share in number of operated holdings has reduced from 26.50 to 17.69 percent during this period. The medium (owning 2 to 10 hectares of land) are 13.22 percent operating 43.61 percent area and large holders (owning more than 10 hectare of land) account for only 0.57 percent of total holdings operating 9.44 percent area as of 2015-16. Overall, we see that there is increase in marginal land holders while in other farm size categories the situation is opposite. Considering land inequalities in specific, we see that inequalities in land distribution as the literature suggests, have reduced after land reforms and change in economic setup. But, still they exist and marginalisation of landholdings is an issue.

In order to measure the inequalities we have calculated gini coefficient of the land distribution pattern by taking data from four consecutive agriculture census viz. 2000-01, 2005-06, 2010-11, and 2015-16. Table 3.9 showcases state wise inequality levels viz. Haryana and Rajasthan have highest level of inequality followed by Sikkim, Jharkhand, Delhi, Tamil Nadu. Gujarat, Maharashtra and Uttar Pradesh also have significant level of inequality with 0.44, 0.44 and 0.42 percent gini coefficient[6] respectively in 2010-11. A similar trend is seen during 2015-16, 2005-06 and 2000-01.

Table 3.9: State-wise Gini Coefficient for Land Distribution in India for 2010-11, 2005-06 and 2000-01

State	Gini Coefficient (2015-16)	Gini Coefficient (2010-11)	Gini Coefficient (2005-06)	Gini Coefficient (2000-01)
Haryana	0.54	0.54	0.54	0.54
Rajasthan	0.54	0.54	0.54	0.54
Sikkim	0.50	0.53	0.54	0.52
Jharkhand	NA	0.51	NA	NA
Goa	NA	0.51	NA	0.55
Delhi	0.47	0.50	NA	NA
Assam	0.49	0.49	0.48	0.50
Chhattisgarh	0.49	0.49	0.50	0.51
Chandigarh	NA	0.48	NA	NA
Himachal Pradesh	0.46	0.47	0.48	0.48
Tamil Nadu	0.46	0.46	0.47	0.48
Madhya Pradesh	0.45	0.46	0.46	0.47
Karnataka	0.47	0.46	0.48	0.48
Gujarat	0.41	0.44	0.43	0.42
Andhra Pradesh	0.45	0.44	0.47	0.48
Maharashtra	NA	0.44	0.43	0.43
Meghalaya	0.43	0.43	NA	NA
Uttar Pradesh	0.41	0.42	0.42	0.43
Uttarakhand	NA	0.41	0.46	0.47

[6]A higher value of gini coefficient represents higher inequality i.e. 0 means perfect equality while 1 represents perfect inequality.

Arunachal Pradesh	0.44	0.39	0.39	0.35
Jammu & Kashmir	0.38	0.39	0.40	0.39
Kerala	0.36	0.38	0.39	0.40
Tripura	0.36	0.38	NA	NA
Punjab	0.34	0.37	0.35	0.35
Odisha	0.33	0.36	0.40	0.40
Manipur	0.34	0.35	NA	0.42
Bihar	NA	0.34	0.38	NA
West Bengal	0.31	0.31	0.32	0.33
INDIA	0.51	0.53	0.54	0.53

Source- Estimated from Various Rounds of Agriculture Census (2000-2016)
Note: NA denotes not available

From above data, we may conclude that land distribution is uneven and in some states the distribution pattern is far more unequal.

Another dimension to land inequality is groundwater accessibility in agriculture. By the very nature of the resource, groundwater extraction is largely a private initiative of farmers which is conditioned by their size of land holding, savings and investment capacities. Land inequalities pose a threat to irrigation facility to small and marginal farmers. It is this land inequality which is highly skewed towards large farmers and they have huge capital investment and relatively better consolidation of land holdings which makes groundwater abstraction viable (Dhawan, 1982, p.7 and Shah, 1993, p.5). In such situation, small and marginal farmers and even large farmers with fragmented holdings depend on WEM owners to irrigate their crops, which led to emergence of an informal groundwater market with varied ramifications (Patel and Patel, 1970, p.6; Shah, 1985, p.25; Kolavalli et al., 1993, p.63; Pant, 2004, pp.9-10; Singh and Singh, 2003; 2006, pp7-8). Sharma and Sharma (2006, pp.46-47) opined that these groundwater markets have facilitated in mitigating inequality in terms of providing physical access to the irrigation water, particularly among the resource- poor small farmers in many cases.

Nayak (2009) also elaborated on this issue and concluded that distributional inequity in land often leads to elites having greater access to groundwater irrigation. This is well evident from Minor Irrigation Census data with reference to land-holding wise ownership of groundwater schemes (dugwells, shallow-tubewells and deep tubewells) in all states of the country. From Appendices, Table 3.10A, we observe that its ownership in all states is highest with medium landowners i.e. 40.53 percent on all India level, followed by small category farmers (29.49 percent) marginal farmers (26.62 percent) and large category (3.44 percent) during 2013-14.In the period of fourth and third minor irrigation census, 34.33 percent and 30.52 percent medium landholders own groundwater schemes respectively. In case of Small farmers, one may assess that 29.49 percent had access to groundwater in 2013-14 while 30.71 percent had in 2006-07, 32.86 percent in 2000. Overall, only 26.62 percent of marginal landowners possess groundwater schemes as per fifth minor irrigation census. The share of big landholders was 3.44 percent according to fifth minor irrigation census, 2.77 in 2006-07, 3.55 percent in 2000-01. Anatomizing data, we found that in case of all landholding size group accessibility to groundwater has reduced over the years, except in medium category. Such inequality in ownership of groundwater schemes is extremely high in Punjab, Rajasthan, Haryana and Uttar Pradesh. Focusing on the latest estimates on number of groundwater schemes owned by different landholding sizes, we see that distribution pattern is highly uneven in Haryana wherein as per 2013-14 data, 84.81 percent accessibility is by medium category farmers while only 3.50 large farmers, 19.19 small farmers and 0.15 marginal farmers had groundwater either dugwells/shallowells or deep-tubewells. In Punjab medium landowners have higher access to groundwater as 73.56 percent of them access to groundwater followed by small (14.29 percent), large (8.03 percent) and marginal (4.10 percent) landholders respectively. Rajasthan also showcases a higher number of medium category farmers possessing groundwater viz. 61.29 percent, 19.22 percent small category farmers had access while only 8.63 percent owned groundwater schemes. In Uttar Pradesh the situation is not so grave but disparities do exist with 46.51 medium landowners having groundwater schemes followed by small (30.69 percent), marginal (18.55 percent) and large (4.22 percent).

We tried to estimate the inequalities by calculating the gini coefficient for all groundwater schemes. Such analysis of land distribution inequality and groundwater irrigation schemes, reveal that states which have high land distribution disparity also possess grave inequities in groundwater accessibility. The gini coefficient figures with reference to groundwater schemes are high in Bihar (0.76), Rajasthan (0.77), Assam (0.66), Odisha (0.57), Haryana (0.56), Delhi (0.47) Madhya Pradesh (0.46), Punjab (0.44), and Uttar Pradesh (0.36).

These states lead in land ownership inconsistency and as well as in ownership of groundwater schemes.

Table 3.10 – Inequity in Number of Operational Holdings in with Number of Groundwater Schemes in India

States	Gini Coefficient (2000-01)	Gini Coefficient (2006-07)	Gini Coefficient (2013-14)
Andaman & Nicobar	NA	0.20	NA
Andhra Pradesh	0.25	0.24	0.33
Assam	0.23	0.66	0.69
Bihar	0	0.76	0.79
Chandigarh	NA	0.53	NA
Chhattisgarh	0.37	0.45	0.46
Dadra & Nagar Haveli	NA	0.11	NA
Delhi	0.44	0.47	0.32
Goa	0.06	0.08	0.09
Gujarat	-0.01	0.09	-0.003
Haryana	0.65	0.56	0.70
Himachal Pradesh	0.54	0.49	0.33
Jammu & Kashmir	0.45	0.74	0.16
Jharkhand	NA	0.26	0.33
Karnataka	-0.02	0.67	0.17
Kerala	0.05	-0.45	0.08
Madhya Pradesh	0.31	0.46	0.36
Maharashtra	0.20	0.21	0.22
Meghalaya	NA	-0.50	NA
Odisha	-0.04	0.57	0.40
Puducherry	NA	-0.38	0.44
Punjab	0.09	0.44	0.40
Rajasthan	0.24	0.77	0.47
Tamil Nadu	0.23	0.35	0.31
Tripura	NA	0.44	NA
Uttar Pradesh	0.27	0.36	0.28
Uttarakhand	0.35	0.63	0.59
West Bengal	0.76	0.11	0.37
All India (Average)	0.27	0.35	0.34

Source- Ministry of Jal Shakti, Department of Water Resources, 3rd, 4th and 5th Minor Irrigation Census

Note: NA denotes Not Available

Table 3.10 presents a linkage of inequity in land ownership and deep tubewells. Thus, the primary reason for such unequal accessibility of groundwater is that land rights and water rights are linked. The consequence of such a legal framework is that only the land owners can own groundwater. As the demand for irrigation has increased with the spread of modern crop production technology, existing owners of tube wells have enjoyed unchallenged de facto ownership right on the community's groundwater resources. In effect, thus, ownership rights on water are given or denied through the rights to establish modern water extraction machines (Shah, 1991, pp.11-12). It also implies that rich landlords can be rich water lords (Singh, 2002, p.7). It is argued that the present de facto water rights system not only distorts resource allocation but also leads to negative equity and ecological effects (Saleth, 1996, pp.56-57). Dhawan (1975, p.9) has commented that the accentuation of external diseconomies that are invariably encountered in the unregulated exploitation of an "ill-defined-ownership" resource like groundwater has been totally neglected while appraising the superiority of "new groundwater water extraction technology". These legislative externalities further reinforce technological externalities. Farmers make private investments assuming that they have absolute rights to the groundwater water aquifer beneath their land. These situations arise not only due to the nature of the resource but also due to the existing institutional arrangements and policy frameworks (Vaidyanathan, 1996, p.11).As a result of this lack of appropriate legal framework, any management system attempting to directly regulate groundwater extraction would be open to legal challenge. On a practical level this means that there is no legal basis for taking action against individuals or groups who damage groundwater availability for others or violate management agreements. For example, groups investing in recharge structures would have no legal means of preventing overlaying land owners from exploiting the newly created resource. Thus, lack of clear cut property rights over groundwater will greatly complicate any management groups (Moench, 1992). This situation also has heavy negative implications for future users and adds tremendously to the costs faced by the current users (Moench and Janakarajan, 2006, pp.18-19). Several scholars have highlighted that the aforementioned states are the ones where groundwater markets are prevalent. Sharma et.al (2006, pp.43-44) in their study on Rajasthan conducting farm size wise analysis revealed that about 45 per cent of the small farmers were involved in buying of groundwater, whereas only 2 per cent indulged in selling activity. About 95 per cent of non-users of water were small farmers and remaining were semi-medium farmers.

Pandey (2014, p.2670) in study on groundwater irrigation in Punjab clearly mentioned that groundwater access disparities have significant and increasing social and economic costs. Farmers are being confronted with the need to move to deeper wells with inevitable increase in cost of farming, making it especially difficult for small and marginal farmers and leading to creation of water markets. Mukherjee et.al. (2004) in their study on West Bengal groundwater scenario stated that informal groundwater markets have emerged as an important institution in the region. Other scholars viz. Dubash, Shah have conducted studies in different parts of country and found that expansion of groundwater, distributional inequities have created groundwater support services markets.

Checking such disparities in land and groundwater schemes ownership with groundwater development, one may conclude that these imbalances have affected groundwater abstraction adversely. Groundwater development is extremely high in Haryana, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh and data assessment reveals that it is these states which have high inequalities in land distribution and groundwater accessibility.

$$\text{Groundwater Development} = -32.17 + (209.30)\ \text{Gini Coefficient of Land} + e_i$$

Further, regression analysis suggests that there is 209.30 units increase in groundwater development if there is a unit rise in gini coefficient of land inequality. Thus, we may conclude that there is a link between distribution pattern disparities and groundwater over-abstraction and depletion. The R-squared is 0.39 and the t-value is 1.95.

3.3.3. Farmer's Income/ Poverty

Taking up two economic indicators as a proxy for economic variables, we performed a regression analysis using population percentage below poverty line and Net State Domestic Product (2011) as independent variables and stage of groundwater development as dependent variable.

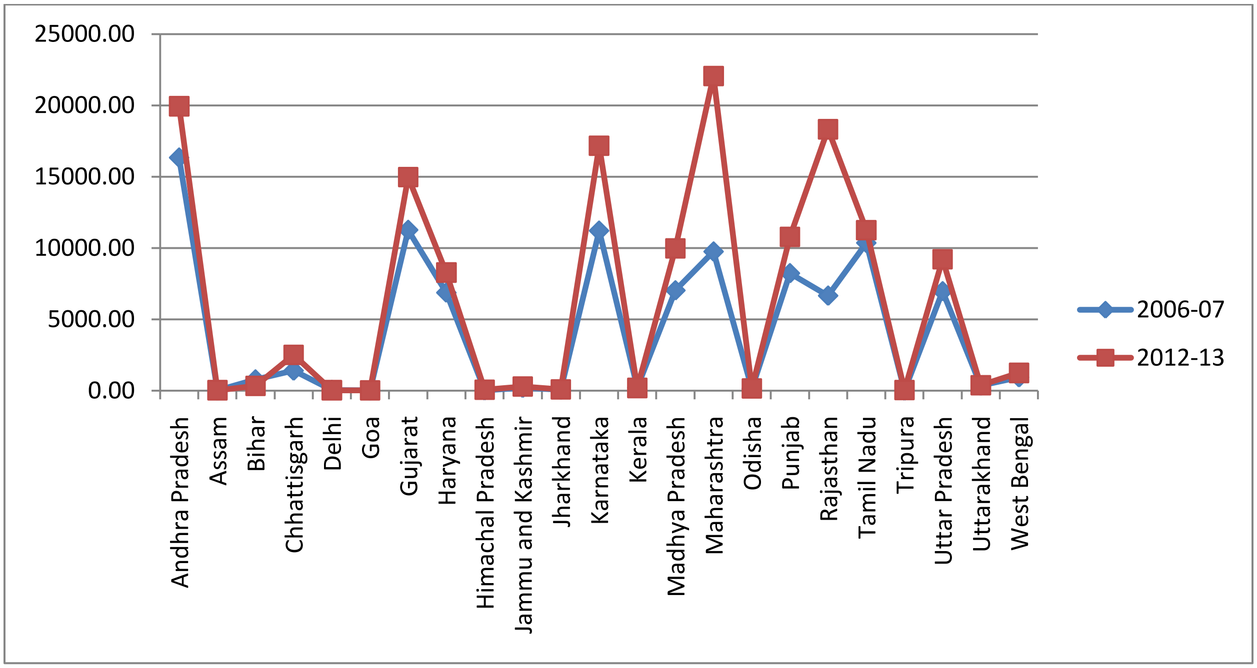
$$\text{Groundwater Development} = -223.07 + (-0.013)\ \text{popBPL2011} + (24.06)\text{NSDP} + e_i$$

The results show that with a unit increase in poverty, groundwater development would reduce by 0.013 units while rise by 24.06 units if there is a unit rise in Net state domestic product. There exist a negative and statistically significant relationship with the proxy indicator of poverty i.e. population below poverty line while a positive and statistically significant relationship with indicator of economic growth viz. Net State Domestic Product. The latter result depicts that economic growth up to some extent raises environmental degradation and poverty does not exacerbates environmental degradation. The R-square is 0.51 and the t-values are 5.07 and -2.03. Several scholars have extensively and critically studied the linkage between environmental degradation and poverty. Some concluded that poverty impedes resource depletion and degradation while others stated otherwise. Musoma (2016, pp.22.23) concluded that "livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capability and assets, while not degrading the resources base". So, accordingly when income from farming increases and farmer's own livelihood issues get resolved, they would focus on environmental sustainability. Environment and poverty linkage has been a controversial one with few stating that poor people exert extreme pressure on natural resources to fulfill their needs. A study conducted to estimate this in Pakistan stated that usually environmental sustainability is believed to alleviate poverty but conversely one of the most serious obstacles to sustainable development is poverty. Farmer poverty clubbed with illiteracy, authoritarian rule, inequalities and corruption may impede groundwater development. Rural people have extensive knowledge about their environments, and about the sustainable use of marginal areas. However, many of these people are being squeezed by a number of interacting processes. Economic and political factors, such as the privatization of common property resources, inappropriate land use policies, can negatively impact rural people (FAO, 2012). Broad demographic changes, such as population growth, resettlement, migration, urbanization, and movements of refugees can also impact rural communities. These pressures frequently change the land-person ratio in an area and place additional pressure on the resource base. Bhattacharya and Innes (2006) in their study highlighted that there exists a bi-directional linkage between environment degradation and poverty. On one hand rural poverty exacerbates environmental degradation while on the other the results indicate that the vegetation degradation spurs rural poverty. So, there exists a bi-directional relationship.

3.3.4. Electricity/Energy Subsidy and Groundwater

Electricity consumption in agriculture sector has soared in almost all the states since last few years due to massive rural electrification. Figure 5 shows the consumption of electricity (in KWh) during the period 2006-2013). Considering region wise energy consumption in agriculture sector as per 2012-13, data suggests that Western region leads in consumption with 49558.99 million KWh followed by Southern region (48606.95 million KWh), Northern (47393.56 KWh), Eastern(1823.56 million KWh) and North-East region(79.14 million KWh). Maharashtra, Gujarat and Madhya Pradesh are the major consumers in Western region. The states which lead in northern region are Rajasthan, Punjab, Haryana and Uttar Pradesh. Andhra Pradesh and Karnataka share in energy consumption is highest in Southern region. West Bengal and Bihar hold the top rank in eastern region while it is Assam and Tripura which consume the most electricity in agriculture sector in North East region.

Figure 5- Electricity consumption for Agricultural purposes-state wise-2006-2013(in KWh)



Source - Computed from Ministry of Agriculture (2006-2013), Electricity consumption for Agricultural purposes data, GOI, India

After 1970s most of the states in India subsidized power consumption in agriculture sector through adoption of a flat-rate tariff system (Swain & Charnoz, 2012, p.23). Such low electricity prices of power to agriculture made groundwater irrigation likeable and profitable for farmers. In the inception phase of pump adoption, diesel technology was favored and farmers in all the states purchased small centrifugal pumps. It was so because significant subsidies were provided on irrigation equipments as well as on diesel. However, in the ensuing phase, rural electrification brought rapid changes in the irrigation patterns, this lead to an increase in installation of electric pumpsets (Shah, undated). In order to assess the share of electric pumps, analysis of distribution of wells on the basis of source of energy has been made. The percentage share of electric pumpsets across all the states over three consecutive Minor Irrigation Census has been estimated.

Table 3.11 shows the percentage share of electric pumps in case of dugwells and their growth rate in different states of the country. At India level, the share of electric pumps was 63.99 percent in 2000-01; it rose to 68.55 percent in 2006-07, increased again to 85.67 percent in 2013-14. As per latest data i.e. 5th MIC, the share of electric pumps in lifting water from dugwells is more than 60 percent in Jammu & Kashmir (99.32 percent), Gujarat (98 percent), Karnataka (98.29 percent), Kerala (98.21 percent), Maharashtra (97.63 percent), Tamil Nadu (94.15 percent), Madhya Pradesh (92.76 percent), Himachal Pradesh (86.69 percent), Uttarakhand (67.79 percent). In majority of the states, the use of electric pumpsets with reference to dugwells has increased significantly except Andhra Pradesh and Assam. This clearly depicts that electricity is the dominant source of energy in fetching water from dugwells. Although, as groundwater depths have increased with rapid abstraction of water, the utility of dugwells has reduced. Considering the growth rate of electric pumpsets in case of dugwells in all states, data depicts negative growth rate in few of the states. This implies that the number of dugwells and the use of electric pumps to lift water from them has reduced over 2000-01 to 2013-14. The highest negative GR is calculated for Haryana (-36.97 percent) followed, Andhra Pradesh (-17.04 percent), Jammu & Kashmir (-14.61), Bihar (-11.08), Chhattisgarh (-8.15 percent), Himachal Pradesh (-6.63 percent), Kerala (-4.83 percent), Jharkhand (-4.55 percent) and Karnataka (-2.72 percent). The highest positive CAGR has been estimated for Odisha (7.50 percent) followed by West Bengal (7.11 percent), Gujarat (5.87 percent), Uttarakhand (3.15 percent), Maharashtra (3.02 percent), Assam (2.24 percent) and Uttar Pradesh (2.07 percent). The overall growth rate of electric pumps with reference to dugwells is low (0.92 percent) because with rising water depletion dugwells have become defunct. Deep wells have replaced dug and shallow wells and most of the irrigation takes place through them in present times (Jain, 2018).

Table 3.11: State Wise Percentage Share and Growth Rate of Electric pumpsets in case of Dugwells (in percent)

States	3 MIC	4 MIC	5 MIC	Growth Rate
Andhra Pradesh	82.29	76.96	59.08	-17.04
Assam	5.84	1.31	5.77	2.24
Bihar	9.07	0	16.97	-11.08
Chhattisgarh	56.77	17.98	84.25	-8.15
Goa	52.11	61.27	68.54	1.29

Gujarat	45.96	55.99	98.68	5.87
Haryana	47.19	17.29	91.67	-36.97
Himachal Pradesh	70.36	87.56	86.69	-6.63
Jammu & Kashmir	90.67	96.74	99.32	-14.61
Jharkhand	1.14	0.67	1.49	-4.55
Karnataka	86.44	85.29	98.29	-2.72
Kerala	80.32	91.26	98.21	-4.83
Madhya Pradesh	83.55	83.53	92.76	1.21
Maharashtra	88.2	93.27	97.63	3.02
Odisha	3.66	3.95	12.17	7.50
Rajasthan	36.25	38.71	57.57	0.75
Tamil Nadu	72.84	84.8	94.15	0.43
Tripura	3.47	13.5	10.39	4.53
Uttar Pradesh	5.36	5.04	8.7	2.07
Uttarakhand	14.46	5.09	67.79	3.15
West Bengal	1.91	2.52	38.76	7.11
Total	63.99	68.55	85.67	0.92

Source- Estimated from Ministry of Jal Shakti, 3rd, 4th and 5th Minor Irrigation Census, Department of Water Resources, GOI, India.

Table 3.12 shows the state wise percentage share and growth rate of electric pumps in case of shallow wells. At macro level, the share of pumpsets using electricity as source of energy has increased by 14.2 percent since 2000-01 with it being 39.01 percent as per 3rd MIC, 38.43 percent in 4th MIC and 53.21 percent in 5th MIC. The latest data shows that the percentage share of electric pumps is more than 90 percent in majority of the states except Uttar Pradesh, Uttarakhand, West Bengal, Assam and Haryana. Analysing the growth rate of electric pumps in case of shallow wells table shows that at national level its use has increased by 2.38 percent annually. The rise has been phenomenal in West Bengal (58.08 percent), followed by Jharkhand (23.87 percent), Gujarat (16.23 percent), J & K (15.15 percent), Rajasthan (12.42 percent), Maharashtra (11.69 percent) etc. Negative growth rate has been registered only in Andhra Pradesh, Assam, Haryana, Punjab and Uttarakhand.

Table 3.12: State wise Percentage Share and Growth Rate of Electric pumpsets in case of Shallow Wells (in percent)

States	3 MIC	4 MIC	5 MIC	Growth Rate
Andhra Pradesh	95.78	95.64	94.27	-4.11
Assam	0.66	0.07	0.35	-1.34
Bihar	4.36	0.00	6.31	0.12
Chhatisgarh	87.78	53.74	99.67	6.02
Goa	96.67	58.10	98.70	7.69
Gujarat	82.58	88.10	99.41	16.23
Haryana	58.60	11.49	89.13	-5.10
Himachal Pradesh	63.34	80.30	92.77	9.95
Jammu & Kashmir	90.82	96.28	99.66	15.15
Jharkhand	25.71	14.85	78.02	23.87
Karnataka	98.40	96.09	99.71	3.68
Kerala	87.86	96.82	99.48	3.32
Madhya Pradesh	95.12	93.64	96.88	1.98
Maharashtr	90.68	95.25	97.99	11.69
Odisha	34.92	35.35	60.95	8.03
Punjab	72.89	83.42	93.10	-2.54
Rajasthan	25.29	35.66	77.16	12.42
Tamil Nadu	80.68	86.54	88.60	2.45
Tripura	52.89	87.06	99.56	11.18
Uttar Pradesh	12.63	9.87	13.77	0.17
Uttarakhand	16.44	13.80	14.31	-2.91
West Bengal	0.04	18.20	25.47	58.08
Total	39.01	38.43	53.21	2.38

Source- Estimated from Ministry of Jal Shakti, 3rd, 4th and 5th Minor Irrigation Census, Department of Water Resources, GOI, India

Table 3.13 presents the state wise percentage share of electric pumps and their growth rate in case of deep wells. At macro level, the share of pumpsets run by electricity has increased since 2000-01 with it being 90.80 percent as per 3rd MIC, 85.90 percent in 4th MIC and 96.61 percent in 5th MIC. In all the states, electric pumpsets exercise major control in agriculture sector. The latest available data (5th MIC) shows that the percentage share of electric pumps is more than 90 percent in majority of the states except Uttar Pradesh, Uttarakhand, West Bengal, Assam, Bihar and Jammu & Kashmir. Analysing the growth rate of electric pumps in case of deep wells table 4 shows that at macro level its use has increased at 13.04 percent annually. The rise has been phenomenal in Punjab, Haryana, Karnataka, Chhattisgarh, Kerala, Andhra Pradesh Madhya Pradesh and Rajasthan.

Table 3.13: State wise Percentage Share and Growth Rate of Electric Pumpsets in case of Deep Wells (in percent)

States	3 MIC	4 MIC	5 MIC	GR
Andhra Pradesh	98.52	98.26	99.68	11.50
Assam	58.82	22.21	74.70	-1.28
Bihar	51.84	0.00	10.09	-8.86
Chhatisgarh	99.43	58.53	99.73	22.74
Goa	96.67	76.60	100.00	-10.87
Gujarat	96.44	80.41	99.19	-8.33
Haryana	84.77	10.75	96.18	18.77
Himachal Pradesh	94.59	97.03	99.70	8.73
Jammu & Kashmir	70.00	98.75	28.99	2.78
Jharkhand	3.57	19.36	63.99	51.99
Karnataka	93.75	NA	99.83	88.61
Kerala	40.09	93.71	99.66	25.51
Madhya Pradesh	91.03	88.21	98.65	12.70
Maharashtra	96.72	97.72	98.16	4.19
Odisha	86.85	35.87	89.55	6.52
Punjab	80.57	96.56	99.05	36.30
Rajasthan	91.99	79.53	95.52	16.20
Tamil Nadu	82.89	91.73	96.67	8.14
Tripura	91.67	95.18	100.00	2.30
Uttar Pradesh	74.38	58.56	64.59	5.43
Uttarakhand	81.99	66.84	68.66	0.46
West Bengal	90.62	91.80	81.78	4.97
Total	90.80	85.90	96.61	13.04

Source-Estimated from Ministry of Jal Shakti, 3^{rd}, 4^{th} and 5^{th} Minor Irrigation Census, Department of Water Resources, GOI, India. Note: NA denotes not available

Data analysis of the distribution of Dug wells, Shallow Tube wells Deep Tube wells on the basis of source of energy depict two phenomenon viz. 1) declining groundwater levels; 2) rising electric pumps usage outshining diesel pumps in agriculture sector. Groundwater depletion and degradation is much higher in areas with electric pumps (Mukherji, Shah, & Giordano, 2012, p.9). This implies that where electric pumps have been installed to extract deep groundwater it has exaggerated the problem i.e. have further declined groundwater (Gandhi and Namboodiri, 2009, pp.11-12). Electric pumps are best suited for fetching deep water, so there has been astounding rise in their share with reference to deep tube wells especially in Punjab (36.30 percent), Haryana (18.77 percent), Rajasthan (16.20 percent), Madhya Pradesh (12.70 percent), Tamil Nadu (8.14), Andhra Pradesh (11.60 percent), Himachal Pradesh (8.73 percent) and Uttar Pradesh (5.43 percent). Although, there are certain other factors behind rapid rise in electric pumps in India but much of the credit for such increased share of deep tubewells and usage of electric pumps goes to low power tariff and subsidies for irrigation.

Checking out the linkage between them (table 3.14), we cross tabulate the tariff rate[7] with electric pumpsets number and are able to conclude that states viz. Uttar Pradesh which has the largest agriculture consumer base has a relatively lower tariff rate of 115 paisa/KwH so is the case in other groundwater stress regions viz. Haryana (25), Gujarat (190), Maharashtra (220) and Delhi (282) as provided in Report on Tariff and Electricity Supply in India (2014), Ministry of Power, Government of India. This might have promoted the use of electric pumpsets in these areas and posed a challenge towards groundwater management. The average price at which power is supplied to agricultural consumers is significantly low if we consider the implications of low energy tariff on groundwater use. Farmers injudiciously consume water and let it go waste for hours. According to Shah and Scott (2004, p.149), such pumping behaviour can be easily understood by through the lens of economics. The large difference between the high fixed cost for a well and the relatively low operating costs militates against conservationist behaviour by those who pump groundwater. In order to recover the high capital investment, the tendency is to maximize the volume pumped. In addition to the lower power tariff, growing power subsidies have become a financial burden to the state governments and are on the rise in these critical states. The removal of metering and introduction of highly subsidized tariff of electricity led to high levels of power (and groundwater) use per hectare.

Table 3.14: State wise Average Power Tariff for Agriculture Sector and Power Subsidy in India (effective from 2013)

States	Avg. Rate (P/KWh)	Tax/Duty (P/KWh)	Total (P/KWh)
Andhra Pradesh	79	0	79
Arunachal Pradesh	310	0	310

[7]Source-Report on Tariff and Electricity Supply in India (2014), Ministry of Power, Government of India

Assam	386	10	396
Bihar	110	4	114
Chhattisgarh	143	0	143
Delhi	282	14	297
Goa	120	20	140
Gujarat	190	0	190
Haryana	25	0	25
Himachal Pradesh	113	11	124
Jammu & Kashmir	68	15	82
Jharkhand	60	2	62
Kerala	152	15	167
Madhya Pradesh	335	0	335
Maharashtra	220	0	220
Manipur	272	2	275
Mizoram	127	0	127
Meghalaya	180	6	186
Orissa	110	2	112
Punjab	425	55	480
Rajasthan	401	4	405
Tamil Nadu	0	0	0
Uttar Pradesh	115	8	123
Uttarakhand	110	15	125
West Bengal	392	0	392

Source-Ministry of Power (2014), Report on Tariff and Electricity Supply in India (2014), GOI, India

From table 3.15, we may see that on an average during 2007-2014 highest amount of subsidy has been provided in the state of Andhra Pradesh (8429 crores) followed by Rajasthan (7131.29 crores),Tamil Nadu(5758.86), Maharashtra (5240.71), Punjab(4960.71), Haryana(4815.29), Gujarat (3400.43), Karnataka (3229.29) Uttar Pradesh (3176 crores) and Madhya Pradesh (3044 crores). A point worth considering over here is that it is these states which are critical in terms of groundwater development. All the nine critical states (Punjab, Andhra Pradesh, Karnataka, Haryana, Gujarat, Rajasthan, Madhya Pradesh, Maharashtra and Tamil Nadu) fall in high subsidy providing states.

Table 3.15: State- wise Subsidy (in Rs. crores) on Power to Agricultural Consumers in India (2007 2014)

States/UT	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	Average	GR
Andhra Pradesh	4868	6807	7192	7215	9423	11177	12321	8429	16.74
Assam	1	1	5	8	8	9	7	5.57	38.31
Bihar	397	488	515	248	364	243	230	355	-8.70
Chhattisgarh	197	513	502	452	684	714	687	535.57	23.14
Gujarat	3049	3128	2618	3339	3454	3893	4322	3400.43	5.99
Haryana	3122	3699	4983	4271	6994	5202	5436	4815.29	9.68
HP	6	5	-3	-1	19	20	19	9.29	21.18
J&K	95	108	152	110	99	136	125	117.86	4.68
Jharkhand	39	42	30	32	37	49	65	42	8.89
Karnataka	3280	3869	3134	1969	3057	3540	3756	3229.29	2.28
Kerala	62	72	85	79	108	149	126	97.29	12.55
Madhya Pradesh	2190	1803	1879	1859	2639	3126	3044	2362.86	5.64
Maharashtra	2928	3259	3715	4742	6710	6837	8494	5240.71	19.42
Punjab	4054	3790	4485	4283	4919	6236	6958	4960.71	9.42
Rajasthan	3024	4934	6961	6975	8439	9693	9893	7131.29	21.84
Tamil Nadu	4422	5458	6267	5568	6193	6395	6009	5758.86	5.24
Uttar Pradesh	1526	1956	2495	2837	4173	4252	4999	3176.86	21.87
Uttarakhand	62	64	81	71	90	97	112	82.43	10.36
West Bengal	258	271	400	568	459	252	357	366.43	5.56
Goa	1	2	3	4	5	5	5	3.57	30.76
Puducherry	20	16	22	25	20	23	23	21.29	2.36
India	33363	39391	45530	44662	57901	62053	66988	49984	12.32

Source- Indiastat.com (Power and Energy division, Planning Commission, Govt. of India)

Power subsidies also play an important role in groundwater exploitation in India. Electricity subsidies have enabled farmers to access power at prices below the marginal cost of supply, thereby lowering the overall cost of irrigation and groundwater extraction. From the 1990s to 2002, the electricity subsidy to agriculture has increased manifold. Consequently, over 40 percent of the state's budget deficit is accounted for subsiding electricity (Singh et al., 2006, p.1). Shah (2011, p.135) points out that this subsidized electricity in agriculture is one of the major challenges for groundwater management. According to Salunkhe and Deshmukh (2012, p.43) electricity subsidies occupy second largest share in total subsidies provided to agriculture sector. Taking groundwater development and energy indicators we performed a regression analysis. Groundwater development has been considered as dependent variable while power tariff to agricultural consumers (X_1) and power subsidy(X_2) to agriculture sector has been used as independent variables.

Groundwater Development = 33.59 + (-0.02) Power Tariff + (0.005) Power Subsidy + e_i

The regression result presented in equation 1, depicts that there exist a positive and significant relationship between groundwater development and power subsidy while a negative link is witnessed with power tariff. The results reveal that groundwater development will reduce .028 units when there is a unit rise in power tariff while it will increase by 0.005units with a unit rise in power subsidy given to agricultural consumers. The R-squared is 0.29 and the t-values are 0.87 and 3.25. Subsidised electricity has increased irrigation (Jaghdani and Brummer (2015, p.1), improved agricultural yields, lowered food prices thereby benefitting consumers (Briscoe and Malik, 2006, pp.1-2) but harming groundwater. Punjab, Andhra Pradesh, Karnataka, Haryana, Gujarat, Rajasthan, Madhya Pradesh, Maharashtra, Uttar Pradesh and Tamil Nadu have developed a precarious groundwater situation which is getting worse every year. Percentage of electric pumps to total pumps in different districts of India has increased (Shah Et.al., 2012, p.6). A study compared areas and found that groundwater stress has peaked in areas where electric tube wells dominated. Free and unmetered power also weakened incentives for water harvesting and groundwater management, as well as sustaining traditional and new surface water bodies (Shah 2009, p.4). In 2001, the World Bank estimated farm power subsidies to be around "US$6 billion a year - equivalent to about 25 percent of India's fiscal deficit, twice the annual public spending on health or rural development, and two and a half times the yearly expenditure on irrigation" (Monari, 2002, p.1). Removal of meters on tube wells has undermined energy accounting in power utilities and impaired their internal accountability systems. While total electricity generation has been increasing steadily, so have the transmission losses. The removal of metering and introduction of highly subsidized tariff of electricity led to high levels of power (and groundwater) use per hectare (Rao, 2008 cited in Shah 2009, p.4). Different initiatives have been taken up by different states so as to conserve groundwater resources. Andhra Pradesh have promulgated groundwater laws while Punjab introduced a law banning paddy transplantation before fourteenth of June and this reportedly had the effect of reducing groundwater withdrawals by up to 9 percent (Singh 2009, p.365), but at the same time exacerbated energy problem by increasing peak demand during that limited window of transplanting. Other initiatives include community management of groundwater in Andhra Pradesh, introduction of efficient irrigation technologies and government or community led initiatives of managed aquifer recharge. Given the severity of the energy irrigation nexus problems, several states have tried different ways of managing it through energy side interventions. Experience across states is mixed. For example, Jyotirgram scheme of feeder segregation to improve quality and quantum of supply to village habitat has been very successful in Gujarat. Under the program, farmers are charged a flat rate tariff, allowing some cost recovery. A distinctly different power regime is found in West Bengal which has metered all its tube wells and now charges farmers at near-commercial rates, and offers them good quality power round the clock. There is no subsidy on agricultural power in West Bengal (PFC 2010). The West Bengal strategy is a textbook economics solution (Mukherjee et.al, 2009, p.5530).

There are eight states which are at various stages of implementing feeder segregation schemes. These are Rajasthan, Gujarat, Andhra Pradesh, Haryana, Punjab, Karnataka, Maharashtra and Madhya Pradesh. This has solved problem of low voltage and oversupply of power to agricultural farmers. Punjab embarked on a similar path of feeder segregation, which they call Urban Pattern Supply. So far, they have segregated 95 percent of all feeders (Pandey et.al, 2016, p.2670)**.**

3.3.5. Farmer Literacy/Awareness

After the seminal work of Schultz (1964, p.198), the importance of education in agricultural development has been widely affirmed. Education enhances the farming skills and productive capabilities of the farmers (Weir, 1999, pp.3-4). It enables them to follow some written instructions about the application of adequate and recommended doses of chemical and other inputs (Appleton and Balihuta, 1996, p.415; Huang and Luh 2009, p.266). Again, numeracy helps them to calculate the costs and benefits of adopting a particular farming technology. But, the empirical assessment of that hypothesis has remained inconclusive (Asadullah and Rahman 2009, p.1; Lockheed et al. 1980, p.37; Narayanmoorthy, 2000, p.511). No consensus has so far been agreed upon among the experts who studied the impact of farmer education on farm productivity. A study on farmer’s education and environmental concern displayed that educational status, age and information accessibility had statistically significant influence on environmental knowledge, attitude and awareness of framers. Insufficient information, lack of organized training centers and poor environmental education provision were some of the constraints in improvement of environmental knowledge and behavior of farmers (Adem, 2017, p.75). Considering the status of awareness among farmers regarding environmental degradation a study revealed that only 23 per cent of the farmers in Tamil Nadu were highly aware about the environmental problems created by the indiscriminate application of modern inputs (Umanath et.al, 2016, p.1). Experience, education and extension contact were the major factors determining the perception and awareness about environmental degradation. A large number of farmers are unaware about the harmful and serious impacts their activities are causing to the environment. For practicing sustainable agriculture, the farmer must be aware to greater degree because his work is likely to involve even longer hours, his knowledge must be deeper and his skills sound as these play a critical part in steering the venture to success (Singh and George, 2012, p.39). In developing countries farmers usually are from weak economic and educational background. This prevents them from obtaining access to the modern advances in the field of agricultural research (Sharma, 2010, p.1). In view of this, providing adequate basic vocational training (Chen et.al,2009, p.461) can prove to be beneficial for enhancing farmer's and farm productivity Thus, there is an urgent need to organize training programmes by developed countries in developing and underdeveloped countries to promote sustainable farming. Further, community involvement makes an individual more environmentally friendly. An individual with greater attachment to the community is likely to be more socially responsible. They are also more likely to have better exposure and access to information about the importance of the environment and environmentally friendly practices (Munasib, 2008, pp.3-4).

3.3.6. Cropping pattern

Several international and international studies have concluded that cropping pattern and groundwater depletion has a close relationship. Crops which have a high water requirement must not be grown in arid or semi-arid areas. For example, in Punjab where farmers mine groundwater to grow rice which is an agro-ecologically misfit crop has lead to decline in water levels (Sarkar and Das, 2014, p.1). Likewise in Central Uttar Pradesh water-intensive crops, such as paddy, wheat and sugarcane are extremely popular and such crop production is responsible for the depleting groundwater tables in the region. Estimates of Data Envelopment Analysis (DEA) have shown that both buyers and owners of WEMs are technically inefficient in water–use, as the actual use of irrigation water has been found much higher than the optimum level (Srivastava et.al, 2009).Certain crops viz rice, sugarcane are water guzzlers, therefore growing them in areas of water stress would be unsustainable. Farmers majorly stick to the traditional cropping pattern as they consider it to be economically viable but now with changing environmental paradigms there arises a need for shift. Considering precarious water stress, scholars suggest that in order to avoid the groundwater depletion and also to get higher returns, farmers should consider crop diversification. In West Bengal, rice is the main food but a shift away from the rice-rice cropping pattern to rice-potato/onion/jute can be practiced (Pal and Nandi, 2016, p.138). In this context, it should be noted that crop diversification had been one of the suggestions to bring changes in Punjab's agriculture since 1986. Two Johl Committee reports (1986 and 2002) recommended a shift away from the wheat-rice cropping pattern to a wheat-maize one. Studies have thrown light on shifts towards alternative crops in the Kharif season on small farms in response to declining access to irrigation water due to groundwater depletion. Rising groundwater stress has made some farmers to resort to water saving practices such as laser leveling and direct seeding of rice. There was considerable decline in the area under rice crop and the area under sugarcane, fodder, potato, maize and pulses increased on the small and medium farms, over time (Kaur and Vatta, 2015, p.485**)**.

Farmers do not have enough incentives for responding to groundwater scarcity by shifting to suitable cropping pattern that reflects scarcity value of groundwater. Food procurement policies and Minimum Support Prices (MSP) that favor rice and wheat also blunt farmers' response to this scarcity lower their incentives for crop diversification, and moving away from water intensive paddy crop to oilseeds and other crops. This is true in the case of Punjab, where it is now well recognized that "Agricultural diversification will work only if the current system of procurement based on minimum support price (MSP) is changed in favour of new crops because it provides a powerful economic incentive to prolong the wheat paddy rotation" (Singh 2004:5589) as cited in Shah et.al.(2012, pp.3-4).Overall, there is a need to make sustainable crop choices considering the groundwater levels, especially in the case of water intensive crops, as their production is related to the overdraft in India's water bank. In Table 3.16, taking into account the relationship between groundwater development and area under irrigation of principal crops state wise, one may assess that states wherein sugarcane, rice, potato, cotton and wheat is grown more has a higher level of groundwater development. In Uttar Pradesh, wheat, rice and sugarcane are the principal crops, thus, groundwater development is more than 70 percent. Tamil Nadu has majority of the area under irrigation of rice, a high water requirement crop leading to groundwater development of 77 percent. Gujarat, highly groundwater stressed region is engaged in cotton production with an area of 3010 mha under its irrigation. Analysis of data of State-wise irrigated area under different selected crops shows that the main States contributing to irrigated area under rice are Uttar Pradesh, Andhra Pradesh, West Bengal, and Punjab. Irrigated area under wheat was concentrated in the States of Uttar Pradesh, Punjab, Madhya Pradesh, Rajasthan and Haryana. Sugarcane had the highest irrigated area in Uttar Pradesh having its share as more than 40 percent in the total irrigated area under this crop in the country. Sugarcane is one of the most water consuming crop. Therefore, Uttar Pradesh needs to consider growing of sugarcane at such huge level with rising groundwater stress.

Table 3.16: State wise Area (in million hectares) under Irrigation- Principal Crops and Groundwater Development (2015)

States	Rice	Wheat	Sugarcane	Cotton	Maize	GW Dev (Percent)
Andhra Pradesh	3809	6	177	2540	995	45
Assam	2278	35	29	NA	23	14
Bihar	3268	2188	256	NA	714	44
Chhattisgarh	3809	98	19	NA	122	35
Gujarat	785	1146	204	3010	423	67
Haryana	1287	2592	101	647	8	133
Himachal Pradesh	68	400	2	NA	300	71
Jammu & Kashmir	266	291	0	NA	309	21
Jharkhand	1502	171	7	NA	270	32
Karnataka	1296	197	450	869	1340	64
Kerala	198	NA	2	NA	0	47
Madhya Pradesh	2153	5560	111	574	1132	57
Maharashtra	1547	895	1048	4192	1059	53
Orissa	4166	1	10	127	92	28
Punjab	2894	3514	94	420	126	172
Rajasthan	168	3318	6	487	904	137
Tamil Nadu	1830	NA	263	186	342	77
Uttar Pradesh	5869	9846	2228	NA	712	74
Uttarakhand	262	348	102	NA	25	57
West Bengal	5386	335	18	NA	150	40
All-India	**43855**	**30969**	**5144**	**13083**	**9258**	**62**

Source- Ministry of Agriculture and Farmers Welfare (2015), Directorate of Economics and Statistics, GOI, India

3.3.7. Environmental Performance

As there is no specific data on ascertaining groundwater awareness among masses or groundwater management state wise we have used EPI methodology named as Planning Commission environmental performance index (PC–EPI), which calculates EPI scores for the selected criteria for all the states and Union Territories (UTs).

The Criterion Indicators are: air pollution (NO*x*[8], SO*x*[9], and SPM/RSPM[10]), forests (TFC[11] as percentage of state geographical area and contribution to national average, increase/decrease in forest cover, growing stock and afforestation efforts). Water quality (percentage of domestic waste water and surface water quality-DO[12], BOD[13] and TFC and groundwater extraction percentage), waste management (MSW[14], bio-medical and hazardous wastes) and climate change (preparation of State Action Plan for Climate Change, RE[15] growth rate including mini hydro, electricity intensity of SGDP[16]). Simple analysis (table 3.17) reveals that a higher EPI score 0.78 state Andhra Pradesh has 45 percent groundwater development. Sikkim also scores better in environmental performance and so has a lower groundwater development. Southern states viz. Karnataka, Kerala seems to perform better and significantly lower groundwater abstraction percentage. Literature evidences suggest that these states are significantly more concerned and aware about environmental issues. It is their concern which has made them take steps towards groundwater stress.

Table 3.17: Environmental Performance Index (EPI)

States	EPI (2012)
Andhra Pradesh	0.78
Assam	0.64
Bihar	0.44
Chhattisgarh	0.64
Delhi	0.42
Gujarat	0.69
Haryana	NA

[8] Nitrogen Oxide
[9] Sulphur Oxide
[10] Suspended Particulate Matter/Respiratory Suspended Particulate Matter
[11] Total Forest Cover
[12] Dissolved Oxygen
[13] Biological Oxygen Demand
[14] Municipal Solid Waste
[15] Renewable Energy
[16] State Gross Domestic Product

Himachal Pradesh	0.74
Jammu&Kashmir	0.54
Jharkhand	NA
Karnataka	0.68
Kerala	0.63
Madhya Pradesh	0.73
Maharashtra	0.71
Manipur	0.48
Meghalaya	0.65
Mizoram	0.64
Nagaland	0.49
Odisha	0.71
Punjab	0.54
Rajasthan	0.59
Sikkim	0.74
Tamil Nadu	0.66
Tripura	0.56
Uttar Pradesh	0.53
Uttarakhand	0.61
West Bengal	0.53

Source- Planning Commission (2012), GOI, India

In order to have a macro level picture or a broad idea about the relationship between groundwater development and socio-economic indicators, a correlation matrix has been prepared. Table 3.18 clearly depicts that groundwater development has a positive linear correlation with population growth rate, power subsidy, NSDP growth rate, electricity consumption and Human Development scores while possess a negative correlation with poverty, power tariff rate for agriculture sector and environmental performance score.

Table 3.18: Correlation Matrix: Groundwater development and socio-economic factors

Variables	Gw Dev	Population	BPL Pop	Elect. Cons.	Power Tariff	EPI Score	HDI
GW Development	1						
Population	0.44*	1					
PopulationBPL	-0.19	0.07	1				
ElectricityConsumption	0.45*	0.56*	-0.007	1			
Power Tariff	-0.15	0.10	0.18	-0.14	1		
Envt.Performance Score	-0.01	0.21	0.03	0.27	0.17	1	
HDI	0.46*	0.43*	-0.17	0.33	-0.04	0.14	1

Source- Author's Calculation

Note:* denotes statistically significant; Gwdev= Groundwater development, BPL Pop= Population below Poverty line, Elect. Cons.= Electricity Consumption by Agriculture Consumers, EPI= Environmental Performance Index, HDI= Human Development Index.

A positive relation with population means that as and when population rise so will groundwater development. A similar linkage is seen with electricity consumption by agriculture sector i.e. as energy consumption increase (which is an indirect measure of groundwater abstraction) groundwater stress deepens. Human development scores also have a positive correlation with groundwater development, such a result is bit debatable and there is a need to further explore the linkage. An indicator of poverty i.e. population below poverty line has negative link with groundwater development suggesting that poverty does not necessarily aggravates environmental degradation. Power tariff rates and environmental performance scores also had a negative relation i.e. there is an increment in both these variables groundwater abstraction may get reduced.

3.4. Conclusion

This chapter presents the status, extent and dynamics affecting management of groundwater resources across states in India. It also highlights the relationship between land distribution and groundwater accessibility. Through secondary level data it is clear that groundwater is the main source of irrigation and provider of drinking water in India. Agriculture sector is the primal user and so it's the responsibility of this sector to use and manage the blue gold judiciously. Among the states, Uttar Pradesh ranks first in terms of share of replenishable ground water resources and its stage of groundwater development is as high as 74 percent. Data evidences depict that groundwater stress has deepened over the years in Uttar Pradesh and groundwater development is highest in Western region of the state. District wise analysis of groundwater development show that Baghpat district in Western Uttar Pradesh is the only district wherein none of the block is in safe category. Therefore, the study selected it for primary survey.

The chapter presented the trends of inequalities in land ownership and groundwater accessibility over the time period in different states of the country. In addition, the chapter deciphered few major factors affecting groundwater use and management in agriculture sector. Correlation analysis reveals that groundwater development has a positive linear correlation with population growth rate, power subsidy, NSDP growth rate, electricity consumption and Human Development scores on the contrary it possess a negative correlation with poverty, power tariff rate for agriculture sector and environmental performance score. Further, regression analysis show that a positive and statistically significant relationship exist between stage of groundwater development and population, economic growth, power subsidy and a negative relationship with poverty and power tariff.

Chapter IV

Socio Economic Profile of Baghpat, Uttar Pradesh

4.0. Introduction

Water resource preservation is influenced by the high rate of evaporation, limited number of dams, high water runoff, semi-dry climatic conditions, rapid population rise, urbanisation, industrialization, changes in monetary status of individuals, and the general increment in living conditions (Lado, 1997, pg.45). It is clear that the economic estimation of water or explicitly groundwater isn't fixed; rather it is influenced by the conditions (e.g., water scarcity because of dry season or over- pumping), and social and individual inclinations. Exact examinations in groundwater valuation show that groundwater use and its valuation are influenced by economic, social, physical, institutional and attitudinal factors. Various social factors (viz., age, education level, and family size), dissemination factors (awareness, perception), physical factors (soil attributes, land slope, farm divisions), monetary factors (farmer's income, farm size, off-farm activities) and institutional variable (land ownership, land regulations) and other contextual factors (cultural backgrounds, water charges, worry about nature of groundwater, need of insurance measures) have been contemplated broadly by researchers to demonstrate their effect on groundwater use and management (Damigos et.al,2017, pg.6597; Barman and Das, 2010, pg.439; Fan et.al, 2013, pp. 3-4).

The socio-economic variables assume indispensable role in the distribution of resources to various production activities which ultimately affect income generation. Land ownership rights, farm size, family size, family unpaid workers, custom and religious components, on-farm and off-farm business openings, market and credit all affect an individual or household process. In developing nations, agro-ecological and socio-economic conditions vary impressively in both existences. In agrarian setup, the financial and social advancement of the region depends upon land and water ownership as well as accessibility. With rapid rise in population, these assets are being over exploited and business -as- usual (BAU) approach is promoting asset exhaustion. In our study area, family divisions have reduced the per family farm size and competing behaviour among farmers have caused water tables to decline swiftly. Majority of the farmers are either small or marginal but a larger proportion has installed submersibles to access groundwater. However, an informal groundwater market exists to satisfy the water needs of farmers who lack ownership of pumpset. In this context, this chapter presents an appraisal of the socio-economic condition of the study area , in particular, population, area, labour force, occupation, agriculture landscape, irrigation system etc.

4.1. Factors Affecting Groundwater Use and Management in Baghpat District, Uttar Pradesh

4.1.1. Topography

The groundwater availability , distribution and occurrence is not only a result of chance but is the consequence of a blend of climatic, hydrologic, geologic, topographic and soil-framing factors that together structure an incorporated unique groundwater ecosystem within a region and each element is inter-related. Topographical conditions largely influence groundwater depths (King, 1889). Subsequent work showed that topography contributes to groundwater movement/flow across many spatial scales; steeper topography can be associated with deeper water table depths, more regional groundwater flow and increased groundwater imports and exports to surface water bodies (Condon and Maxwell, 2015).

Baghpat town is located on the banks of river Yamuna at 28 deg 57' North Latitude and 77 deg 13' East Longitude. It is 52 km from Meerut City and is on the main Delhi–Saharanpur Highway around 40 km from Delhi toward north (MSME, 2016).

4.1.2. Population and Area

Population rise has been dominant in Baghpat with a 11 percent increase during ten year period between year 2001 to 2011.The district has a total population of 13,03,048 persons with 7,00,070 males and 6,02,978 females (refer table 4.1) and the total area is 1326 sq.kms. The density of population in Baghpat district is 986 people per square kilometer. Out of the total populace, 21.11 percent people lived in urban regions while 78.89 percent in rural areas. Out of all the blocks Baraut has the highest population while Chhaprauli has the least. As population density is high and majority of the population is into farming occupation groundwater use is high in agriculture sector.

Table 4.1: Block wise Total Population of Baghpat District, Uttar Pradesh

S.No.	Block Name	Villages	Persons	Males	Females
1	**Chhaprauli**	27	1,60,532	86,873	73,659
2	**Baraut**	54	3,37,071	1,81,499	1,55,572
3	**Binauli**	58	2,15,503	1,15,963	99,540
4	**Baghpat**	52	2,31,274	1,23,954	1,07,320
5	**Pilana**	51	1,62,502	86,699	75,803
6	**Khekra**	48	1,96,166	1,05,082	91,084
	Total	**290**	**13,03,048**	**7,00,070**	**6,02,978**

Source- Ministry of Home Affairs (2011), Census, Office of General and Census Commissioner, GOI, India.

4.1.3. Climate

According to District Survey Report (2018), the average rainfall is 585.3mm. The climate is subtropical and is characterised by dryness of the air with an intensely hot summer and a cold winter. About 90 percent of the rainfall takes place during the months of June to September. Data on rainfall shows that there have been high variations in recent times (table 4.2). The average annual rainfall in the year 2004 was 526 mm which reduce to 271mm in 2007 but increased again in the subsequent years while in 2012 it has been recorded 322.8mm. During the monsoon season, surplus water is available for deep percolation to groundwater. May is generally the hottest month of the year and January is regarded as the coldest month in this area. The maximum temperature raises upto 46 Celsius while it dips down to 7.90 Celsius in winters. The air is dry during the major part of the year and the months of April, May is the driest months. The humidity levels are also relatively high with an average of 67 percent and average wind velocity 4.61km/ha (MSME, 2016). With climate change, the average rainfall has reduced over the years leading to reduced water levels in rivers and irrigation canals. A map (fig.1) of the area has also been presented to show an overview of the geographical conditions.

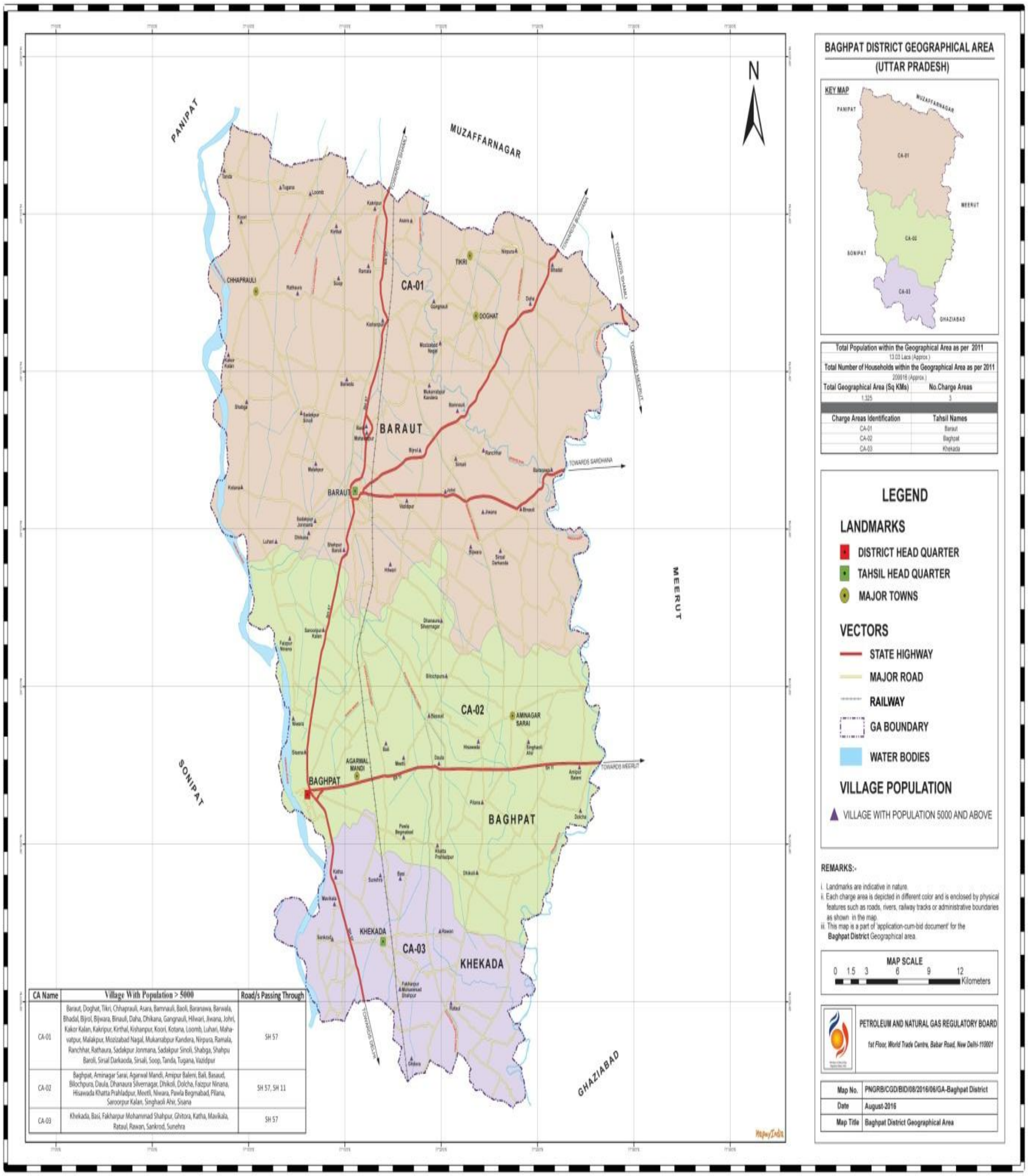
Table 4.2: Monthly and Annual Rainfall (2004-2012) in Baghpat district, Uttar Pradesh (in mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2004	26	0	0	24.5	28.5	17.3	4.5	246.7	59.7	118.7	0	0	526
2005	13.8	48.2	21.8	0	7.3	43.2	217.5	20	172	0	0	0	543.8
2006	0	0	50	1	80.7	129.1	229.3	36	80.3	18.1	1	0	625.4
2007	1	1.9	75.2	0	22.1	133.1	20.6	3.4	14.4	0	0	0	271.6
2008	0	0	0	12.9	86.7	99.9	202.3	197	113.7	0	5.3	0	717.7
2009	0	0	0	0	0	21	200.5	107.3	300	0	0	0	628.8
2010	1.7	11.5	0	1.7	0	26.1	191.2	417.4	348.1	6.4	1.5	2.8	1008.2
2011	0	0	0	0	76.5	87.8	96.1	147.4	215.6	0	0	0	623.4
2012	14.2	0	0	15.9	0	16.3	69.4	135.4	53.1	0	1.8	16.7	322.8
Avg.	**6.3**	**6.8**	**16.3**	**6.2**	**33.5**	**63.7**	**136.8**	**145.6**	**150.8**	**15.9**	**1.1**	**2.2**	**585.3**

Source-Ministry of Jal Shakti (2015), Central Ground Water Board, District Ground Water Brochure, GOI, India

Focusing on the groundwater level in Baghpat district, Appendices table 4.2A shows that over the period 2009-2018, the water table has gradually declined in almost all the hydrograph stations. The water level was as low as 32.04m in village Nirpuda of Binauli block in year 2009 and has fell down further to 34.9 m in 2018. Similarly,substantially low water levels (>20m) prevail in villages viz. Binauli, Kaidwa, Rathaura, Fakharpur, Pusar Pai, Budhh Sani,Bijrol, Pilana etc and the water level has dipped over the stated time period. Thus, depicting that changed rainfall pattern clubbed with other socio-economic factors has made groundwater abstraction increase which has resulted in water table decline in the region.

Figure 6 – Geographical Map of Baghpat district



Source- National Geospatial Data Centre

4.1.4. Socio-Economic Profile

According to Census (2011), Baghpat district has a predominance of Hindu religion followed by Islam and other religions. Major castes are Jats, Yadav, Gujjars, Tyagis and Rajputs besides Dalits and a large number of Muslims. Schedule Caste (SC) constitutes 11.4 percent of total population in Baghpat and currently the region does not have any Schedule Tribe (ST) population. Inequity among different caste and religious groups with reference to groundwater accessibility is witnessed in India.

Focusing on the education factor, which plays a role in water use and conservation behaviour, Table 4.3 shows that the total literacy rate of Baghpat district was 72 percent in 2011 which is greater than average literacy rate 67.68 percent of Uttar Pradesh. Population-wise, out of total 797,970 literates, males were 489,858 while females were 308,112. Also the male literacy rate was 82.45 percent and the female literacy rate was 60 percent.

Table 4.3: Distribution of Population by Sex as per Education Status

S. No.	Block Name	No.of Literates			No.of Illiterates			Literacy Rate (%)		
		Persons	Males	Females	Persons	Males	Females	Persons	Males	Females
1	Chhaprauli	84683	53312	31371	56879	23390	33489	70.14	81.68	56.56
2	Baraut	133236	83036	50200	85979	35790	50189	71.2	81.9	58.55
3	Binauli	122042	75716	46326	79295	32521	46774	71.49	82.69	58.54
4	Baghpat	102212	63450	38762	64879	26751	38128	71.9	82.84	59.12
5	Pilana	99246	60933	38313	63256	25766	37490	72.35	83.36	59.79
6	Khekra	84838	52034	32804	51478	21108	30370	73.23	84.06	60.81
	Total	**626257**	**388481**	**237776**	**401766**	**165326**	**236440**	**71.67**	**82.69**	**58.86**

Source- Ministry of Home Affairs (2011), Census, Office of General and Census Commissioner, GOI, India.

Economic activity distribution helps in analysing the levels of employment in the region which indirectly presents the socio-economic status. Taking into account the pattern of economic activity, table 4.4 shows that out of the total main and marginal workers, 34.17 percent are cultivators, 20.14 percent are agriculture labourers, 5.11 percent are in household industry and 40.48 percent are other workers. A similar pattern is witnessed in all the blocks of the district. Checking out male-female occupation pattern, it is seen that females also largely work as other workers and their percentage is lower than males in all the categories. As far as total working population is considered it is highest in Baraut followed by Binauli, Baghpat, Pilana, Chhaprauli and Khekra.

Table 4.4: Distribution of Workers by Sex in Four Categories of Economic Activity in Community Development Blocks, 2011

S. No.	Block Name	Persons/ Males/ Females	Total population	Total workers (main + marginal)	Category of Workers							
					Cultivators		Agricultural labourers		Household industry workers		Other workers	
					Number	Percent	Number	Percent	Number	Percent	Number	Percent
1	Chhaprauli	Persons	141562	49453	17372	35.13	10473	21.18	5570	11.26	16038	32.43
		Males	76702	38036	14807	38.93	8569	22.53	2375	6.24	12285	32.30
		Females	64860	11417	2565	22.47	1904	16.68	3195	27.98	3753	32.87
2	Baraut	Persons	219215	72334	25772	35.63	17459	24.14	2711	3.75	26392	36.49
		Males	118826	59526	22386	37.61	13392	22.50	1742	2.93	22006	36.97
		Females	100389	12808	3386	26.44	4067	31.75	969	7.57	4386	34.24
3	Binauli	Persons	201337	65495	25358	38.72	15114	23.08	2486	3.80	22537	34.41
		Males	108237	53334	22202	41.63	11518	21.60	1834	3.44	17780	33.34
		Females	93100	12161	3156	25.95	3596	29.57	652	5.36	4757	39.12
4	Baghpat	Persons	167091	56365	16480	29.24	8404	14.91	2163	3.84	29318	52.01
		Males	90201	44695	14440	32.31	6406	14.33	1468	3.28	22381	50.07
		Females	76890	11670	2040	17.48	1998	17.12	695	5.96	6937	59.44
5	Pilana	Persons	162502	51869	17283	33.32	10706	20.64	2993	5.77	20887	40.27
		Males	86699	42297	14856	35.12	8446	19.97	1852	4.38	17143	40.53
		Females	75803	9572	2427	25.36	2260	23.61	1141	11.92	3744	39.11
6	Khekra	Persons	136316	42047	13412	31.90	5845	13.90	1333	3.17	21457	51.03
		Males	73142	35037	11507	32.84	4315	12.32	950	2.71	18265	52.13
		Females	63174	7010	1905	27.18	1530	21.83	383	5.46	3192	45.53
	Total	Persons	1028023	337563	115677	34.27	68001	20.14	17256	5.11	136629	40.48
		Males	553807	272925	100198	36.71	52646	19.29	10221	3.74	109860	40.25
		Females	474216	64638	15479	23.95	15355	23.76	7035	10.88	26769	41.41

Source-Ministry of Home Affairs (2011), Census, Office of General and Census Commissioner, GOI, India.

4.1.5. Agriculture Profile

Agriculture forms an integral part of the daily lives of majority of people in Uttar Pradesh. In the agricultural year July 2012 – June 2013, Uttar Pradesh had approximately 18 million agricultural households which accounted for 20 percent of the total agricultural households in rural India. Average monthly income per agricultural household is the third lowest in Uttar Pradesh as majority of the farmers are small/marginal. UP's agriculture is smallholder dominated, some of whom are subsistence farmers, but many are also commercial farmers trying to get whatever best they can from these small holdings and markets that are in nearby mandis.

Baghpat is a primarily agricultural economy with nearly 70 percent of the district's population involved in it. However, the percentage of small and marginal farmers is highest i.e. 87.6 percent followed by small, medium and large farmers. Popularly known as the sugar basket of India, Western Uttar Pradesh leads in terms of sugarcane production. Farmers in Baghpat also majorly grow sugarcane and wheat. The Total area under agriculture in Baghpat is 109000 hectares out of which 73 hectares are under horticulture cultivation. As per data presented in table 4.5, the Net area sown is 141829 hectares ad irrigated area is 141331.8 hectares. Irrigation penetration is high in all the blocks of the district but unirrigated area is highest in Pilana (164.8 ha) followed by Binauli (116.2 ha) and Khekhra (104.5 ha).

Table 4.5: Block wise Net Area Sown, Irrigated and Un-Irrigated Area of Baghpat (in hectares)

Block Name	Net Area Sown	Area-Irrigated	Total Un-irrigated Area
Chhaprauli	14491.6	14461.1	31
Baraut	54039	53957.2	81.8
Binauli	23990.2	23873.9	116.2
Baghpat	18318.3	18318.3	0
Pilana	17117.4	16952.6	164.8
Khekhra	13873.2	13768.7	104.5
Total	141829.7	141331.8	498.3

Source-Ministry of Home Affairs (2011), Census, Office of General and Census Commissioner, GOI, India.

4.1.6. Water Resources

From the above table it is evident that large proportion of net area sown in Baghpat is under irrigation and only few hectares are un-irrigated. It is necessary over here to assess which source is being extensively used for irrigation in the region. Table 4.6 indicates that tubewell irrigation is predominant in Baghpat with 126229.7 hectares irrigated through it. Dependency over canals have reduced over the time with less rainfall, lack of adequate infrastructure and increased groundwater accessibility.

Table 4.6: Block wise Area Irrigated by Source in Baghpat (in hectares)

Block Name	Canals	Tubewells/Wells	Tanks/Lakes	Water Falls
Chapprauli	391.4	12828.9	0	0
Baraut	1503.1	51028.7	0	0
Binauli	0	22364.2	0	0
Baghpat	463.7	17227.7	0	0
Pilana	188.4	15117.1	0	0
Khekhra	1646.3	7663.1	2129.3	776.9
Total	4192.9	126229.7	2129.3	776.9

Source- Ministry of Home Affairs (2011), Census, Office of General and Census Commissioner, GOI, India.

A shift towards groundwater irrigation has taken a toll on its sustainability. District groundwater brochure published by CGWB elaborates upon the dynamic groundwater resources of the district (refer table 4.7). The data highlights a grave fact that it Baghpat is the only district in the state which has none of its block in safe category. The overall groundwater development is one of the highest with 116.61 percent. Out of all the blocks in the district, the situation is precarious in Binauli and Pilana, where groundwater development is 154.08 and 131.50 percent respectively. Baraut having groundwater development of 85.57 percent is the only less affected block, thus, it falls in semi-critical category.

Table 4.7: Dynamic Groundwater Resource Availability, Use and Development in Baghpat District, Uttar Pradesh

S.No	Blocks-Units	GW Availability (in ham)	Irrigation use (in ham)	Domestic &Industrial (in ham)	GW Dev (%)	Category
1	**Baghpat**	5980.02	5575.50 (93.23)	427.31 (7.14)	100.38	Over-exploited
2	**Baraut**	8612.21	7043.88 (81.78)	310.01 (3.59)	85.57	Semi-Critical
3	**Binauli**	5522.27	9279.30 (168.03)	461.97 (8.36)	154.08	Over-exploited
4	**Chaprauli**	6635.61	7204.20 (108.56)	342.96 (5.16)	113.74	Over-exploited
5	**Khekra**	5908.45	6295.75 (106.55)	372.21 (6.29)	112.85	Over-exploited
6	**Pilana**	5180.39	6481.00 (125.11)	330.98 (6.39)	131.50	Over-exploited
	Total	37838.95	41879.63	2245.44	116.61	

Source- Ministry of Jal Shakti (2015), District Groundwater Brochure, Central Ground Water Board, GOI, India

4.2. Sample Structure, Size and Survey Technique in the Surveyed Areas

Central Groundwater Board District profile of Baghpat served as the base document for selecting the specific blocks within the district. From the secondary data on groundwater availability, utilisation and development we could decipher the most critical and relatively better off blocks with reference to groundwater stress. As per the data, Binauli and Pilana blocks fell under the category of overexploited blocks i.e. have higher stage of groundwater development than other blocks so one village from each of them was chosen for study. From Binauli we selected Mawi Kalan and from Pilana, Pura Mahadev. As there is only one block which comes under semi-critical category, we selected two villages namely Gurana and Vazidpur so that we may capture the inter-village differentials. An equal number of households i.e. 75 were surveyed from each village in order to have a justified representation which makes the total of 300 households in the study. The main objective of this study is to assess the impact of socio-economic variables on groundwater use, management in agriculture sector so specifically the farmer households were selected viz. who own and operate farm lands.

4.3. Socio-Economic Profile of Households in the Study Area

In this part of the chapter an attempt is made to present socio, demographic and economic profile of 300 farmer households. The villages selected were Gurana, Vazidpur, Mawi Kalan and Pura Mahadev of Baghpat district. Throughout this chapter, several aspects such as caste, religion, gender, age, activity status, income, landholding size, education level and other socio-economic dimensions pertaining to the sample households as per different villages have been focused upon.

4.3.1. Social Factors

(a) Religion of Sample Households

Religion is an important social factor as it usually has influence on social and economic development of an individual or family**.** Different religion groups thrive in a secular country viz. India with Hindus being 79.80 percent followed by Muslims (14.23 percent), Christians (2.30 percent) and Sikhs (1.72 percent) etc. (Census, 2011). Our sample is a true representation of the national data with 88.67 percent households practicing Hinduism while 11 percent belong to Islamic faith and only 0.33 percent follows Sikhism. The majority of the households in all the villages belong to Hinduism faith. Table 4.8 shows that in Gurana 86.77 percent follow Hinduism and 13.33 practice Islam. In Vazidpur, 97.33 percent are Hindu households and mere 2.67 are Muslim ones. Out of 75 households sampled in Mawi Kalan, 85.33 percent are Hindu and 14.67 percent follow Islam. Pura Mahadev has one household practicing Sikhism while 85.33 percent are Hindu and 13.33 belong to Islamic faith.

Table 4.8: Village wise Religion of Farmer Households

Village	Hinduism	Islam	Sikhism	Total
Gurana	65 86.67* 24.44**	10 13.33* 30.3**	0 0.00* 0.00**	75 100* 25**
Vazidpur	73 97.33* 27.44**	2 2.67* 6.06**	0 0.00* 0.00**	75 100* 25.00**
Mawi Kalan	64 85.33* 24.06**	11 14.67* 33.33**	0 0.00* 0.00**	75 100* 25.00**
PuraMahadev	64 85.33* 24.06**	10 13.33* 30.30**	1 1.33* 100**	75 100* 25.00**
Total	266 88.67* 100**	33 11.00* 100**	1 0.33* 100**	300 100* 100**

Source- Estimated from Field Survey Data.
Note: * row percentage **column percentage;
Pearson chi2 = 10.25   Pr = 0.114

(b) Caste system

The Indian caste system is an extremely complicated social structure which has witnesses several changes over the period. Constitutionally, untouchability has been abolished and a fair representation to SC/ST and OBC has been guaranteed but in reality the differentials in socio-economic status still exist. Direct or indirect discrimination tend to occur with people belonging to SC/ST communities which can be seen in occupation, income levels or in any other case where it is a matter of preference. According to Sankaran et.al (2017, pg.1), caste membership is ingrained in the society and there are sufficient reasons to say that caste as a type of social identity is one of the most salient with reference to India and social roles are decided through it. Therefore, the study of caste pattern is necessary to understand the dynamics of such complex social structure and its influence on our variables of interest.

As per table 4.9, In Gurana, 46.67 percent of the household belonged to OBC category, 34.67 percent to general and 18.67 fall in scheduled caste category. Vazidpur has 70.67 percent OBC households followed by 2.67 households belonging to General category and 6.67 to SC category. In Mawi Kalan, out of 75 households randomly selected, 49.33 percent were of General category, 29.33 of OBC and 21.33 of SC category. In Pura Mahadev, 45.33 percent households belong to General category, 34.67 percent to OBC and 20 percent to SC category. Overall, out of 300 sample households, 45.33 percent were OBC, 38 percent General category and 16.67 percent were of SC category. This implies that the region is dominated by Other backward class group (OBC) with majority being *Jats*. Baghpat is commonly referred to as 'heartland of Jats'. General category, SC community representation is relatively less and we could not find a single ST household in the sampled villages.

Table 4.9: Village wise Caste of Farmer Households

Village	SC	OBC	General	Total
Gurana	14 18.67* 28**	35 46.67* 25.74**	26 34.67* 22.81**	75 100* 25**
Vazidpur	5 6.67* 10**	53 70.67* 38.97**	17 22.67* 14.91**	75 100* 25**
Mawi Kalan	16 21.33* 32**	22 29.33* 16.18**	37 49.33* 32.46**	75 100* 25**
Pura Mahadev	15 20* 30**	26 34.67* 19.12**	34 45.33* 29.82**	75 100* 25**
Total	50 16.67* 100**	136 45.33* 100**	114 38* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note: * row percentage **column percentage;
Pearson chi2 = 31.38 Pr = 0.000; No ST Household found

(c) Age of the Head of Household

According to Settersten (2017, pp.1-2), "age is often not well theorized. When it is, it is generally assumed to bring decline or risk in various domains (such as cognitive or physical health), but it can also be connected to possibilities of growth (such as wisdom) or considered a buffer of risk (such as having accumulated experience that brings a wider repertoire of coping strategies)".

The data of our sample (table 4.10) reveals that most of the head of the households were of above 60 years (42.67 percent), 37.33 percent had heads in the age group of 45-60 years and just 18.67 percent fall in 31-45 years category in Gurana. A similar pattern could be seen in Vazidpur while in Mawi Kalan and Pura Mahadev, majority of the sampled households had heads within the age group of 45-60 years. Overall, among all the sample households, 40.33 percent households had heads within the age group of 45-60 years, 34.67 percent were headed by above 60 years of age and 21.67 percent had relatively young head of the household within the age bracket of 31-45 years. This indicates that head of the households are majorly middle aged so that they may have experience and adequate physical strength to manage the family and work pressures.

Table 4.10: Village wise Age of Head of the Household

Village	16-30 yrs.	31-45yrs	46-60 yrs.	Above 60yrs.	Total
Gurana	1 1.33* 10**	14 18.67* 21.54**	28 37.33* 23.14**	32 42.67* 30.77**	75 100* 25**
Vazidpur	4 5.33* 40**	12 16* 18.46**	29 38.67* 23.97**	30 40* 28.85**	75 100* 25**
Mawi Kalan	2 2.67* 20**	16 21.33* 24.62**	32 42.67* 26.45**	25 33.33* 24.04**	75 100* 25**
Pura Mahadev	3 4* 30**	23 30.67* 35.38**	32 42.67* 26.45**	17 22.67* 16.35**	75 100* 25**
Total	10 3.33* 100**	65 21.67* 100**	121 40.33* 100**	104 34.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note: * row percentage **column percentage;
Pearson chi2 = 5.60 Pr=0.13

(d) Family Size

Prof. Gary Becker in 'An Economic Analysis of Fertility', published in 1960 stated two things 1)increase in income is accompanied by increased desire for quantity and quality of children, 2) 'if knowledge of contraceptive techniques does not vary with income , the relation between actual fertility and income would equal desired fertility and income'. Such proposition had mixed reactions from scholars worldwide. However, the size of the family is a matter of significance at macro and micro level as it affects the overall well being and growth. Arthur (2005, pg.27) mentions that whenever agriculture is an important activity for poor households, they have an incentive to invest in children to serve as farm labour and assist with household tasks, such as fuel wood and water collection and childcare. Another reason for having large families is that it provides social security, investing in children becomes a way of ensuring care in old age. Family size has an effect on education, income, social and other contextual outcomes. In India, farmers usually prefer to employ their own sons/daughters on field as it helps them in saving money otherwise spent on hiring labourers. Almost all the sample households we visited this pattern could be witnessed with family members working on farms.

Table 4.11 shows that in Gurana, the average family size of Marginal landholders was 5.31; small farmers and medium farm owners had mean family size of 5.9 whereas large landholders had a high average family size of 10. This indicates that large landholders could suffice a large family. In Vazidpur, the average family size of Marginal landholders was 4.29, small farmers and medium farm owners had mean family size of 5.25 and 6 respectively whereas large landholders had a high average family size of 3. In Mawi Kalan, the average family size of Marginal landholders was 4.97, small farmers and medium farm owners had mean family size of 5.35 and 5.81 respectively. In Pura Mahadev, the average family size of Marginal landholders was 5.17, small farmers and medium farm owners had mean family size of 4.64 and 6 respectively whereas large landholders had a high average family size of 3. Overall, a trend of higher family size with increase in landholding ownership could be seen but majorly a nuclear family structure is witnessed.

Table 4.11: Village wise Average Family Size of Farmer Households

	Marginal	**Small**	**Medium**	**Large**
Gurana	5.31	5.95	5.9	10
Vazidpur	4.29	5.25	6	3
Mawi Kalan	4.97	5.35	5.81	NA
Pura-Mahadev	5.17	4.64	6	3

Source- Estimated from Field Survey Data; NA denotes Not Available

(e) House Structure

According to Brink (2014, pg.1), the quality of life of society is affected by a variety of social concerns interacting with one another. Housing is probably one of the key factors. A household with a proper *pakka* house structure is relatively less vulnerable to climatic, sanitation and micro environment pressures. This indirectly promotes the social and economic well being of house members. Another way to look at this indicator is through the economic lens i.e. housing cost as a proportion of income serve as indicator of household’s affordability.

Out of total 75 households in Gurana (refer table 4.12), 77.33 percent owned a *pakka* house, 20 percent lived in semi-pakka while 2.67 in Katchha type of house. In Vazidpur, 84 percent lived in pakka house, 10.67 in semi-pakka and 5.33 in Katchha one. Mawi Kalan had 62.67 percent households with pakka house structure while 37.33 owned semi-pakka type of house. A similar pattern was witnessed in Pura Mahadev wherein 72 percent owned a pakka house and 28 percent resided in semi-pakka house. Overall, 74 percent households out of 300 sample owned pakka house, 24 percent had semi-katchha house and just 2 percent lived in a Katchha house. This data suggests that the economic status of households in sampled villages is relatively better as most of the people could afford to live in a pucca house and a small percentage resides in a katchha type of house structure.

Table 4.12: Village wise Type of House Structure of Farmer Households

Village	Katchha	Pucca	Semi-Pucca	Total
Gurana	2 2.67* 33.33**	58 77.33* 26.13**	15 20* 20.83**	75 100* 25**
Vazidpur	4 5.33* 66.67**	63 84* 28.38**	8 10.67* 11.11**	75 100* 25**
Mawi Kalan	0 0* 0**	47 62.67* 21.17**	28 37.33* 38.89**	75 100* 25**
Pura Mahadev	0 0* 0**	54 72* 24.32**	21 28* 29.17**	75 100* 25**
Total	6 2* 100**	222 74* 100**	72 24* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note: * row percentage **column percentage; Pearson chi2 = 21.91 Pr = 0.00

(f) Education level of Head of the Household

Education is fundamental factor affecting development of an individual's and his/her family unit's social, political, economical and community life. According to Ozturk (2001, pg.1), it improvises the quality of their lives and leads to broad social benefits to individuals and society. Education raises people's productivity, creativity, promotes entrepreneurship and technological advances. In addition, it plays a very crucial role in securing economic and social progress and improving income distribution. According to Burchi (2006, pg.193), education increases the chances of rural poor to escape from poverty and hunger with their own power. Considering the education level of head of the household is necessary as head of the household has the decision making power and control all the aspects of the family. An educated head may promote economic production i.e. make farming more productive and effective.Singh (1973, pg.122) considered education as an important factor in impeding social change. Education has also been observed as an aid towards modernisation (Lerner, 1958, pg.1133). The table given below gives us a view of head's education which plays an important role in their socio-economic development and perception towards different things. Table 4.13 reveals that in Gurana, 24 percent head of the households were illiterate, 18.67 percent educated upto class VIII, 17.33 percent upto class tenth, 13.33 studied upto higher secondary level and just 6.67 percent were graduate. In Vazidpur, 22.67 percent were found to be not literate, 28 percent studied upto secondary level, 17.33 reached higher secondary level. The percentage of head of the household who have done graduation and post graduation was 8 and 5.33 percent respectively. In Mawi Kalan, 33.33 percent were educated upto middle level, 29.33 percent were illiterate and 20 percent attained schooling upto higher secondary level.The percentage of illiterates was 30.67 percent in Pura Mahadev, 28 percent educated upto secondary level and 20 percent passed class XII. Overall, the highest percentage of illiterates was highest in Pura Mahadev and lowest in Vazidpur. Thus, suggesting Gurana and Vazidpur are better in terms of education level as the percentage of illiterates is lower over there.

Table 4.13: Village wise Education of Head of the Household

	Illiterate	Below Primary	Primary	Middle	Secondary	Higher Secondary	Graduate	Post Graduate	Total
Gurana	18 24* 22.5**	7 9.33* 46.15**	4 5.33* 22.22**	14 18.67* 26.92**	13 17.33* 21.31**	10 13.33* 18.87**	5 6.67* 35.71**	4 5.33* 50**	75 100* 25**
Vazidpur	17 22.67* 21.25**	2 2.67* 15.38**	7 9.33* 38.89**	5 6.67* 9.62**	21 28* 34.43**	13 17.33* 24.53**	6 8* 42.86**	4 5.33* 50**	75 100* 25**
Mawi Kalan	22 29.33* 27.5**	3 4* 23.08**	2 2.67* 11.11**	25 33.33* 48.08**	6 8* 9.84**	15 20* 28.3**	2 2.67* 14.29**	0 0* 0**	75 100* 25**
Pura Mahadev	23 30.67* 28.75**	2 2.67* 15.38**	5 6.67* 27.78**	8 10.67* 15.38**	21 28* 34.43**	15 20* 28.3**	1 1.33* 7.14**	0 0* 0**	75 100* 25**
Total	80 26.67* 100**	14 4.66* 100**	18 6* 100**	52 17.33* 100**	61 20.33* 100**	53 17.67* 100**	14 4.67* 100**	8 2.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data

Note: * row percentage **column percentage; Pearson chi2=52.89, Pr=0.00

(g) Sources of Water for Domestic Use

As per Census (2011) the maximum number of households in Baghpat district depends upon hand-pumps for drinking water. In rural areas of the district, 74.53 per cent households were using hand pumps for drinking water, 15 per cent were using Tap water and only 6.3 per cent households were using tubewells. In urban areas almost 40 per cent of the total households of the district were using tap water from treated source, 30.59 percent used hand pump and 12.02 percent got water for drinking purposes from tubewell. In our sampled villages, 63.33 percent households get drinking water from submersible, 28.33 percent through hand pumps, 7 percent use government water supply and just 1.33 percent depends on tanks. Our primary survey data also reveals a different pattern. Table 4.14 depicts that in Gurana, wherein the water level is relatively better off 32 percent use hand pumps for domestic use and a higher percentage (58.67) have submersibles/electric motor pumps at home. In Vazidpur (area near canal), 52 percent use electric pumpsets for fetching water for domestic use, 40 percent use hand pumps and 5.33 percent use piped water supply. In Mawi Kalan village, 68 percent depend upon submersibles/electric motors for withdrawing water for domestic use, 25.33 percent use hand pumps and just 6.67 percent resort to piped water supply. In Pura Mahadev, majority of the population i.e.74.67 percent depends upon submersibles/electric motors for abstracting water, 16 percent use hand-pumps, 6.67 depend upon piped water supply and 2.67 percent households on tanks. This indicates that villages wherein the groundwater level is relatively high (i.e. Gurana and Vazidpur) people do depend upon submersibles/electric motors but the still a significant proportion of population thrives on water from other sources viz. hand pump and piped water supply.

Table 4.14: Village wise Primary Source of Water for Domestic Use

Village	Submersible	Tanks	Hand-pump	Piped Water Supply	Total
Gurana	44 58.67* 23.16**	0 0* 0**	24 32* 28.24**	7 9.33* 33.33**	75 100* 25**
Vazidpur	39 52* 20.53**	2 2.67* 50**	30 40* 35.29**	4 5.33* 19.05**	75 100* 25**
Pura Mahadev	56 74.67* 29.47**	2 2.67* 50**	12 16* 14.12**	5 6.67* 23.81**	75 100* 25**
Mawi Kalan	51 68* 26.84**	0 0* 0**	19 25.33* 22.35**	5 6.67* 23.81**	75 100* 25**
Total	190 63.33* 100**	4 1.33* 100**	85 28.33* 100**	21 7* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note: * row percentage **column percentage; Pearson chi2(9) = 16.68 Pr = 0.05

4.3.2 Economic Factors

(a) Landholding Size

The percentage of small landholders in India is rising rapidly and that of large farmers declining. It is the small farms which provide us the necessary food nutrient and are themselves in condition of starvation. Farm size has several socio-economic connotations ranging from increase in agriculture productivity to better social status. Flinn and Buttel (1980, pg.946) state the work of Coughenor and Christenson on farm size and its relationship with attitude on personal well being, social well being and adequacy of services. They found that small farmers were far more dissatisfied than large farmers. Considering impact of farm size on agriculture productivity, Chand et.al (2011, pp.5-6) in their paper found that small landholders still showcase higher productivity levels in India. Therefore, taking into account all these implications of land sizes an understanding of the percentage of various category landholders in each sample village is necessary.

Table 4.15 presents the picture of frequency and percentage of various categories of landholders within the sample households. Out of 300 households, 59 percent operate on marginal landholdings (0.01-2.50 acres), 26 percent have small landholdings in their possession. Medium and large category farmers are low with 13.33 percent and 1.33 percent respectively. This sample is a fair representation of the landholding pattern of the Baghpat district wherein the number of marginal and small farmers is the highest. In Gurana, 60 percent households belonged to marginal category, 29.33 percent were small farmers, 8 percent medium and just 2.67 percent had landholding of more than 10 acres. Vazidpur also had highest number of marginal farmers (54.67 percent), followed by 26.67 percent small landholder category, 17.33 percent medium farmers and 1.33 percent large landholder. In Mawi Kalan, 60 percent of the sampled households had landholding of less than 2.50 acres and in Pura Mahadev 61.33 percent were marginal farmers.

Table 4.15: Village and Landholding size wise Number and Percentage of Farmer Households

Village	Marginal (0.01-2.50 acres)	Small (2.51-5 acres)	Medium (5.01-10 acres)	Large (Above 10 acres)	Total
Gurana	45 60.00* 25.42**	22 29.33* 27.85**	6 8.00* 15.00**	2 2.67* 50.00**	75 100* 25.00**
Vazidpur	41 54.67* 23.16**	20 26.67* 25.32**	13 17.33* 32.50**	1 1.33* 25.00**	75 (100) 25.00**
Mawi Kalan	45 60.00* 25.42**	20 26.67* 25.32**	10 13.33* 25.00**	0 0* 0.00**	75 100* 25.00**
Pura Mahadev	46 61.33* 25.99**	17 22.67* 21.52**	11 14.67* 27.50**	1 1.33* 25.00**	75 100* 25.00**
Total	177 59.00* 100**	79 26.33* 100**	40 13.33* 100**	4 1.33* 100**	300 100* 100**

Source-Estimated from Field SurveyData

Note: * row percentage **column percentage; Pearson chi2(9) = 5.57 Pr = 0.00

(b) Occupation of Head of the household

Occupation is an indicator of skill, education and income. In all the sample households (table 4.16) we find that head of the household is into self employment and are majorly cultivators. In Gurana, we see that 94.67 percent of the heads are into self employment basically cultivators/crop growers, 2.67 percent are regular salaried, 1.33 percent are doing domestic as well as other side work,1.56 percent. In Vazidpur, 94.67 percent of the heads of the households are self employed and 2.67 are agricultural labourers, 1.33 percent are doing just household chores and 1.33 percent are regular salaried employees. Similar scenario persists in Mawi Kalan and Pura Mahadev wherein 92 percent are into self employment.

Table 4.16: Activity Status of Head of the Household

Village	Agriculture Labour	Domestic work	Others	Regular Salaried	Self Employed	Unpaid Family Labour	Total
Gurana	0 0* 0**	1 1.33* 14.29**	0 0* 0**	2 2.67* 50**	71 94.67* 25.36**	1 1.33* 50**	75 100* 25**
Vazidpur	2 2.67* 100**	1 1.33* 14.29**	0 0* 0**	1 1.33* 25**	71 94.67* 25.36**	0 0* 0**	75 100* 25**
Mawi Kalan	0 0* 0**	2 2.67* 28.57**	2 2.66* 33.33**	1 1.33* 25**	69 92* 24.64**	1 1.33* 50**	75 100* 25**
Pura Mahadev	0 0* 0**	4 5.33* 42.86**	2 2.67* 66.67**	0 0* 0**	69 92* 24.64**	0 0* 0**	75 100* 25**
Total	2 0.67* 100**	8 2.66* 100**	4 1.33* 100**	4 1.33* 100**	280 93.33* 100**	2 0.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data

Note: * row percentage **column percentage; Pearson chi2 = 21.29 Pr = 0.44

Considering activity status of all the people within the age i.e. 15 and above, Table 4.17 shows that in Gurana out of total 274 people in this age group, 37.59 percent are into performing domestic duties, 18.25 percent are working as unpaid family labourers, 16.79 percent are students, 12.04 percent are regular salaried and a minor proportion is into other activities. In Vazidpur, out of total working age population of 218 individuals, 32.11 percent are doing domestic/household work, 24.31 percent are students, 15.14 percent are unpaid family workers and 10.09 percent are into regular salaried job. In Pura Mahadev, the majority of the population is engaged in domestic work, 19.4 percent are students and 10.78 percent serve as unpaid family labour on farms. In Mawi Kalan, the same trend continues i.e. major working age population is doing household chores (44.88 percent), 9.69 percent are studying, 7.87 are into regular salaried jobs, 6.67 work as unpaid family labourers. The percentage of unemployed people is relatively low in all the villages, however from the total number of unemployed, 42 percent are in Pura

Mahadev, 38.46 in Mawi Kalan, 15 percent in Vazidpur and just 3.76 percent in Gurana. Considering unpaid family labour in the same manner, data reveals that its share is highest in Gurana followed by Vazidpur, Pura Mahadev and Mawi Kalan.

Table 4.17: Village wise Activity Status of Total Working age population (15 years and above)

Village	Self Employed	Regular. Salaried	Non[1] Agri.	Agri Labour	UN[2]	Domestic Work	Domestic &Side Work	Student	Services	UFL[3]	Others	Total
Gurana	24 8.76* 24.49**	33 12.04* 34.02**	1 0.36* 25**	3 1.09* 33.33**	1 0.36* 3.85**	103 37.59* 27.25**	10 3.65* 29.41**	46 16.79* 23.71**	0 0* 0**	50 18.25* 40**	3 1.09* 30**	274 100* 28.02**
Vazidpur	19 8.72* 19.39**	22 10.09* 22.68**	1 0.46* 25**	2 0.92* 22.22**	4 1.83* 15.38**	70 32.11* 18.52**	11 5.05* 32.35**	53 24.31* 27.32**	1 0.46* 100**	33 15.14* 26.4**	2 0.92* 20**	218 100* 22.29**
Pura Mahadev	23 9.91* 23.47**	22 9.48* 22.68**	1 0.43* 25**	2 0.86* 22.22**	11 4.74* 42.31**	91 39.22* 24.07**	8 3.45* 23.53**	45 19.4* 23.2**	0 0* 0**	25 10.78* 20**	4 1.72* 40**	232 100* 23.72**
Mawi Kalan	32 12.6* 32.65**	20 7.87* 20.62**	1 0.39* 25**	2 0.79* 22.22**	10 3.94* 38.46**	114 44.88* 30.16**	5 1.97* 14.71**	50 19.69* 25.77**	0 0* 0**	17 6.67* 13.6**	3 1.18* 10**	254 100* 25.97**
Total	98 10.02* 100**	97 9.92* 100**	4 0.41* 100**	9 0.92* 100**	26 2.66* 100**	378 38.65* 100**	34 3.48* 100**	194 19.84* 100**	1 0.1* 100**	125 12.78* 100**	12 1.22* 100**	978 100* 100**

Source- Estimated from Field Survey Data

Note- * row percentage **column percentage; Pearson chi2 = 59.79 Pr=0.003

[1] Non agriculture income employed in non agriculture sector viz. livestock and dairy, horticulture etc.

[2] UN denotes unemployed

[3] UFL refers to Unpaid Family Labour

(c) Sources of Income

Main Source of Income

As farmer households were only considered in this survey majority of the households stated cultivation as their primary source of income. Table 4.18 presents that in Gurana, 100 percent mentioned cultivation as main source of income while in Vazidpur 93.33 percent stated so and 6.67 percent cited other than agriculture to be their main earning source. In Mawi Kalan, 98.67 percent considered cultivation to be their primary source of income and just 1.33 did not. In Pura Mahadev, 96 percent stated cultivation to be the main source of income and 4 percent mentioned otherwise.

Table 4.18: Village wise Distribution of Households as per Main Source of Income

Village	Cultivation	Other than agriculture	Total
Gurana	75 100* 25.77**	0 0* 0**	75 100* 25**
Vazidpur	70 93.33* 24.05**	5 6.67* 55.56**	75 100* 25**
Pura Mahadev	72 96* 24.74**	3 4* 33.33**	75 100* 25**
Mawi Kalan	74 98.67* 25.43**	1 1.33* 11.11**	75 100* 25**
Total	291 97* 100**	9 3* 100**	300 100* 100**

Source-Estimated from Field Survey Data

Note: * row percentage **column percentage; Pearson chi2= 6.75 Pr = 0.08

Secondary Source of Income

A number of studies from developing countries have suggested that diversification of rural economy towards non-farm activities has considerable potential to augment farmers' income and reduce rural poverty (Birthal et.al, 2014, pg.37). When the households are unable to earn sufficient income from cultivation they are forced to do non-farm work. The dynamics in agriculture sector are changing with less earning, higher employment opportunities and increased aspirations among rural people. Studies confirm that against the common perception of agriculture being the dominant source of income for farm households, these households earn close to half of their income from non-farm activities. This nonfarm income is more important for the households at lower end of land distribution. In table 4.19 below, the frequency and percentage of households involved in other side activities/business in all sampled villages has been given. In Gurana, 61.33 percent are engaged in livestock/dairy production and 22.67 percent in non-agricultural activity. In Vazidpur, the percentage of households involved in dairy business id 56 percent, in other agricultural activity is 2.67 percent and in other than agri.activity is 12 percent while 22.67 percent state no secondary source of income. In Mawi Kalan, 28 percent households are into dairy production and a relatively higher number i.e.41.33 percent termed non agricultural activity to be their secondary income source. In Pura Mahadev, 56 percent are into livestock/dairy business, followed by 22.67 percent into other than agricultural activity. The percentage of people with no secondary income source was high in Gurana and Pura Mahadev followed by Vazidpur and Mawi Kalan.

Table 4.19: Village wise Distribution of Households according to Secondary Source of Income

Village	Cultivation	Livestock	Other agri. activities	Other than agriculture	No secondary source	Total
Gurana	0 0* 0**	46 61.33* 30.46**	0 0* 0**	17 22.67* 22.97**	12 16* 19.67**	75 100* 25**
Vazidpur	5 6.67* 55.56**	42 56* 27.81**	2 2.67* 40**	9 12* 12.16**	17 22.67* 27.87**	75 100* 25**
PuraMahadev	3 4* 33.33**	42 56* 27.81**	1 1.33* 20**	17 22.67* 22.97**	12 16* 19.67**	75 100* 25**
Mawi Kalan	1 1.33* 11.11**	21 28* 13.91**	2 2.67* 40**	31 41.33* 41.89**	20 26.67* 32.79**	75 100* 25**
Total	9 3* 100**	151 50.33* 100**	5 1.67* 100**	74 24.67* 100**	61 20.33* 100**	300 100* 100**

Source- Estimated from Field SurveyData
Note:* row percentage **column percentage; Pearson chi2(12) = 35.58 Pr = 0.00

(d) Income Pattern

Income is an important parameter to define the economic status of the respondents. The income of the respondents depends on the occupation, land holdings and control on the other sources of income. The economic status in the rural areas depends on the agriculture, agriculture related activities and small business activities in addition to service in the organized or unorganized sector. In the above table we have seen that a significant percentage of households in all the sampled villages do not entirely depend upon agriculture for their survival rather they have a secondary source of income. The area under study is mainly dependent on agriculture and people are engaged in agricultural activities. However some respondents are working as waged labourers in the fields of the people with larger land holdings. Some people in the area are going to work as industrial workers in industrial units located in the nearby area or even to Delhi.

Table 4.20 presents an overview of the total income of sample households. The mean income of households in Gurana village is Rs. 6, 57,017, highest in all four villages, followed by Mawi Kalan (Rs. 457170), Vazidpur (Rs. 446874) and Pura Mahadev (Rs. 441615). The income difference was significant between Gurana and other villages.

Table 4.20: Village wise Mean, SD, Maximum and Minimum Yearly Total Income of Households

Village	Mean	SD	MAX	MIN
Gurana	6,57,017.73	4,44,459.11	21,36,750.00	1,00,000.00
Vazidpur	4,46,874.53	3,42,484.80	18,00,000.00	6,940.00
Mawi Kalan	4,57,170.16	3,84,316.43	24,20,000.00	1,03,000.00
Pura Mahadev	4,41,615.13	2,98,288.03	13,39,250.00	16,040.00

Source- Estimated from Field Survey Data

In order to further analyse the income distribution pattern, quintile wise table has been prepared. The macro picture presented in table 4.21 shows that 20.67 percent households fall in second quintile (Rs.200000-300000) quintile,20.33 percent in fourth (Rs. 500000-800000), 20 percent in first (Rs.6940-200000), 19.67 percent in fifth (above Rs. 800000)and 19.33 in third (Rs. 300001-485725). Thus, depicting that income pattern is not skewed within the sample. However, the situation is different when we consider it at village level. In Gurana, majority of the households i.e. 30.67 percent fall in fifth quintile, followed by 26.67 percent in fourth, 18.67 percent in third, 16 percent in second and mere 8 percent in first. In Vazidpur, 28 percent households fall within first quintile of income followed by 25.33 percent in fourth, 16 percent each in second and third and just 14.67 percent in fifth. In Mawi Kalan, 25.33 percent have income within Rs.200000-300000 bracket, 24 percent within third quintile, 22.67 percent in first quintile, 20 percent in fifth quintile and just 8 percent in fourth quintile. In Pura Mahadev, majority (25.33) of the households have income within Rs.2-3 lakhs/annum, followed by first and fourth quintile. The percentage of households in third and fifth quintile is 18.67 and 13.33 percent respectively.

Table 4.21: Quintile wise income distribution of Sample households

Village	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	Total
Gurana	6 8* 10**	12 16* 19.35**	14 18.67* 24.14**	20 26.67* 32.79**	23 30.67* 38.98**	75 100* 25**
Vazidpur	21 28* 35**	12 16* 19.35**	12 16* 20.69**	19 25.33* 31.15**	11 14.67* 18.64**	75 100* 25**
Mawi Kalan	17 22.67* 28.33**	19 25.33* 30.65**	18 24* 31.03**	6 8* 9.84**	15 20* 25.42**	75 100* 25**
Pura-Mahadev	16 21.33* 26.67**	19 25.33* 30.65**	14 18.67* 24.14**	16 21.33* 26.23**	10 13.33* 16.95**	75 100* 25**
Total	60 20* 100**	62 20.67* 100**	58 19.33* 100**	61 20.33* 100**	59 19.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note:* row percentage **column percentage; Pearson chi2=27.75 Pr=0.00

4.4. Socio Economic Vulnerability Index (SEVI)

Socio Economic Vulnerability Index (SEVI) is developed by taking social and economic indicators pertaining to the sampled villages. The social factors include caste, age, house structure (pakka house), source of water (hand-pump) for domestic use and education (literate or otherwise) while economic factor includes total income and land size.

Socio Economic Vulnerability Index (SEVI) is estimated by using the above mentioned factors based on methods adopted by UNDP (HDR, 2016) and Iyengar and Sudarshan (1982) methodology. It is basically a summary of measure of variable's achievement levels in all the chosen dimensions.

The result of Socio-economic Vulnerability index (presented in table 4.22) suggest that Gurana village is relatively less vulnerable with a total score of 0.79 followed by Vazidpur

(0.70), Pura Mahadev(0.27) and Mawi Kalan(0.19). The reasons for high score of Gurana are that the income levels of households in this area were higher than other villages and so is their land ownership in terms of marginal farmlands. We considered marginal landholding in this context primarily because of two reasons-a) Overall, the percentage of marginal landholdings were the highest in the sample size b) marginal farms were found to be more productive.

Another reason for low ranking of Pura Mahadev and Mawi Kalan villages is the overall education is better in Gurana and Vazidpur. The type of house structure also influences the socio-economic status. Data analysis reveals that people in Gurana and Vazidpur are able to afford *pakka* houses than the households in other two villages. The source of water is an important point to focus in the vulnerability assessment. The groundwater levels are lowest in Mawi Kalan and Pura Mahadev. Both these villages fall in over-exploited blocks i.e. Binauli and Pilana while Gurana and Vazidpur are in semi critical block i.e. Baraut. Thus, source of water viz. hand pumps have turned dry in Mawi Kalan and Pura Mahadev making them more vulnerable.

Table 4.22: Socio-Economic Vulnerability Index[1]

Village	Income	Caste	Land	Age	Education	House Type	Water	Total Score	Rank
Gurana	1.00	0.41	0.8	1	0.99	0.68	0.66	0.79	1
Vazidpur	0.03	1	0	0.91	1	1	1	0.70	2
Pura Mahadev	0.00	0.12	1	0	0	0.43	0.38	0.27	3
Mawi Kalan	0.07	0	0.8	0.34	0.16	0	0	0.19	4

Source- Estimated from Field Survey Data

4.5. Conclusion

The sampled villages viz. Gurana, Vazidpur, Pura Mahadev and Mawi Kalan selected for the study are located in Baghpat district of Uttar Pradesh. Baghpat is one of major prosperous and agrarian district of western region of Uttar Pradesh. The land is fertile and is mainly used for sugarcane cultivation. Majority of the farmers have marginal or small farms and are entirely dependent on groundwater for irrigation. Installation of powerful submersible pumpsets has

[1]**Score near to 1 indicates low vulnerability while closer to 0 indicates high vulnerability**

made timely irrigation possible but has taken a toll on the health of groundwater ecosystem. Baghpat is the only district in Uttar Pradesh which has none of the development blocks in safe category as per CGWB. The average stage of groundwater development in the district is 116 percent and it is more than 100 percent in five out of six blocks. Out of the selected four villages, Gurana and Vazidpur showcase a relatively better socio-economic condition and the status of Pura Mahadev and Mawi Kalan is worse. The result of Socio-Economic Vulnerability index confirms that Gurana village is relatively less vulnerable with a total score of 0.79 followed by Vazidpur (0.70), Pura Mahadev (0.27) and Mawi Kalan (0.19). The issues pertaining to socio-economic characteristics are discussed in depth in the following chapters.

Chapter V

The Various Dimensions of Agriculture in the Surveyed Area

5.0. Introduction

India has primarily been an agrarian economy which has now with globalisation and run for economic growth become a service sector led country. However, even today agriculture remains to be the biggest employer to the country's working labour force. Massive changes took place in the agriculture ecosystem after the initiation of Green revolution which benefitted the farmers and country as a whole. The country's production and productivity levels rapidly soared and it became self reliant in production of staple crops especially rice and wheat. However, this new arrangement set in another round of discussions on farm productivity, returns on cultivating, and innovation availability. The rural areas are under extreme stress due to absence of adequate returns to farming and availability of adequate farm and off-farm employment (Raman and Khan, 2017, p.15). The present agrarian crisis has similarities with the situation that spurned in agriculture sector after the independence era in India. During that time, manufacturing sector was growing at a fast pace and service sector was concentrated in few pockets of the country, thereby not solving the problem of surplus labour and productivity in agriculture (Patnaik, 2003, p.40). Further, it is observed that agricultural crisis in India is not limited to some advanced states like Maharashtra, Kerala etc. where farmers have shifted to cost intensive and perilous cash crops; even the state that were at the forefront or were the torch bearers during the green revolution period, using relatively advanced farming techniques and the states lying in the most fertile region of the country have witnessed higher levels of farmers' indebtedness, declining productivity, frequent crop failures and increased incidence of farmer suicides. The most worrisome situation is of states like Uttar Pradesh, Bihar and Orissa etc. where majority of the population is dependent on agriculture, the speed of industralisation is very slow and the scope of service sector is limited to construction and banking sector. Researchers contended that the underlying driver of the agrarian crisis is that agribusiness is not anymore a gainful monetary activity when contrasted with different endeavors. It implies that the income generated from agriculture isn't adequate to meet the consumption needs of the farmers. Also, consequently, except if agribusiness is made a productive endeavor, the present problem cannot be tackled. The related elements affecting the agriculture include: reliance on rainfall, high imports of agricultural items, decrease in agrarian subsidies, diminishing size of homesteads, absence of simple and formal credit to farmers and reliance on local moneylenders, low investment by government, absence of extension and training services (Dhas, 2009, p.12).

This chapter tries to address two basic objectives. Firstly, to understand India's agrarian crisis. Secondly, to observe this crisis through the lens of primary data collected from different villages of Baghpat district. The chapter has been broadly divided into four sections. The first section includes introduction, objectives and methodology of the chapter. The second part deals specifically with the review of literature. The third part captures the data analysis of primary data and the last section has the summary and conclusion.

5.1. Agrarian Situation: Trends and Issues

India's production of food grains has been increasing every year, and is among the top producers of several crops such as wheat, rice, pulses, sugarcane and cotton in the world but lags behind in growth and yield levels. The agriculture growth has been inconsistent with 5.8 percent in 2004-05 to -0.2 percent in 2014-15. Considering agricultural yield, report published by Deshpande (2017, p.2) stated that agriculture productivity of majority of the crops in India is lower than the other producing countries such as China, Brazil and the United States. There is not a single factor which is the cause of such inconsistencies and bad performance of the sector but a multitude of factors play a role. According to scholars, main issues affecting agriculture sector include the decreasing sizes of agricultural land holdings (Deshpande, 2017, p.2; Lowder et.al., 2016, p.16), inadequate irrigation infrastructure and access (Dhawan, 2017, pp.9-12; Shah, 2011; Thakkar, 1999, pp.3-6), lack of sophisticated technologies on farms (FICCI, 2015, p.9; Simsi et.al., 2016, p.23), imbalanced use of fertilizers/pesticides which hampers soil fertility (Kumar and Indira, 2017, p.45; Bhattacharya et.al., 2015, p.3528), lack of access to institutional credit (Kumar et.al., 2017, p.45; Golait, 2007, p.79), climate change (Mahato, 2014, p.2; Mendelsohn, 2008, p.5), illiteracy and unawareness among farmers (Gaurav and Singh, 2012, p.358; Das, 2015, p.40), low returns to farming (Raman and Khan, 2017, p.13; Dev, 2012, p.3), limited procurement by government and low prices of agriculture produce (Chatterjee, 2016, p.1; Pandey, 2019) .

Currently, India's agriculture sector majorly constitutes of marginal and small farmers whose condition has not changed significantly in a positive manner. The fragmentation of landholdings due to increase in population, breakdown of joint family structures transmuted medium/large farms to small landholdings (Singh, 2012, p.113). These small/marginal farmers suffered even during the time of Green Revolution as they were unable to afford the necessary inputs which lead to widening of gaps amongst the owners of different landholding categories and ultimately benefitting the large farmers (Sebby, 2010, p.3). Regular famines, droughts, mechanisation and other changing dynamics of agriculture in India required use of expensive technologies which favoured the 'best endowed farmer in the best endowed area' thereby negatively affecting the small farmers. Such a situation might have uprooted the small farmers but they have for their survival and competition with large farmers took the route of taking credit from local moneylenders, friends or relatives. Money lenders taking advantage of the turbulent times, unawareness and lack of institutional credit facilities for farmers charge extremely high interest rates (Zwerdling, 2009, p.1). In addition to these issues, government support in terms of subsidies and irrigation is also skewed in India. High public investment increases the profit levels of landowners and motivates them to invest on their farm which apparently leads to rise in productivity (Das, 1999, p.29). Literature suggests that such public investments also took place in areas where there was more number of large commercial farms as they could crack better deals with government officials (ibid). This fostered development only in areas which were already advanced and wealthy. Inspite of all these problems, a large number of studies have provided convincing evidence that crop productivity is higher in case of small/marginal farms as compared to the large ones (Kadapatti and Bagalkotper, 2014, p.123) while some have opined otherwise (Bhalla and Roy,1988, p.55; Chadha, 1978, p.78). Other opportunities have also widely opened for marginal and small farmers in terms of increasing scope of human labour intensive enterprises such as fruits and vegetables, dairy, livestock etc. The other important opportunities open in favour of marginal and small farmers due to implementation of Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) during Eleventh Five Year Plan through employment generation, land reclamation and water management.

Apart from the problems faced by small/marginal farmers in specific there exists a large set of issues which affect the entire agrarian community. Availability of adequate water for irrigation is becoming a global concern. Lack of awareness about micro and precision irrigation techniques among farmers is taking a toll on water levels. The Economic Survey (2015-16) mentioned that farmers in India practice flood irrigation wherein the farm is filled with water and it slowly seeps into the soil. Such method is unsustainable and should be replaced by modern irrigation techniques. Excessive and imbalanced use of fertilizers and pesticides is another issue which plagues Indian agriculture. Farmers in order to increase their production without having complete knowledge about its application, use it generously on different crops which have affected soil fertility in many areas. Agriculture machinery is also an important part of agriculture production process as it enables faster and easy tilling, harvesting etc. A large proportion of Indian farmers are unable to generate as much income as to invest in machines and other agriculture equipments. So, it is usually the medium and large farmers who can afford the latest technologies. However, with relatively increased access to institutional credit and government subsidies for tractors, machines etc. has made even the small farmers own agricultural tools and machinery. Agriculture price policy is also a matter of great concern in India’s agriculture system. Minimum support price, procurement price are all instruments of protecting farmers and consumers. The MSP for rice and wheat cover almost 20 percent of cost (Dev and Rao, 2010, p.174). They have been able to achieve around 20% over total costs to the farmers of both rice and wheat. However, MSP, without an effective procurement mechanism, does not guarantee that prices would not fall below the floor set by the government. In this context, it is more important to see the prices received by the farmers than the MSP per se (Tripathi, 2010, p.2). The price received by farmers had been lower than MSP for a large number of crops since a long period.

Taking into account all the above stated issues plaguing the agriculture sector, we have made an attempt in this chapter to understand the agriculture situation in four hydrogeologically, socially and economically different villages of Baghpat district.

5.2. Agricultural Scenario of Surveyed Villages in Baghpat District, Uttar Pradesh

5.2.1. Production and Productivity

Several studies have been conducted on the economic viability of small and marginal farmers in the country. The small and marginal holdings constitute about 86.2 per cent as per 2015-16 Agriculture Census while the percentage of semi-medium/medium farmers is just 13.2 percent. Large disparities exist in terms of cultivated area wherein small farmers cultivate on 47.3 percent area and other categories on 43.6 percent area. As far as contribution to output is considered it is higher for marginal and small farmers as compared to their share in area. According to FAO, the small land holders contribute more than 40 percent to total production in India suggesting high production and productivity levels within this category. There has been a fierce debate about the relationship between productivity and farm size in India and globally. According to Gollin (2018, p.2), across countries there is a weak but positive relationship between farm size and yield levels. Within countries, the relationship between farm size and yield is often negative. Sen (1962, p.243) suggests that this relationship arises from imperfections in land and labour markets, such that poor households use family labour intensively on small plots, leading to high land productivity. In India, unpaid family members majorly work on farms and therefore the high productivity on small farms is achieved. Berry and Cline (1979, p.2) stated that "small farm sector makes better use of its available land than does the large farm sector". Several other scholars also concluded that productivity declines with rise in farm size but recently this relationship has witnessed criticism. Ghose (1969, p.27) in his paper mentioned that inverse farm size productivity association is mere ''static superiority''. According to him, once the backwardness in technology usage is over this negative relationship will disappear. Bhalla & Roy (1988, p.55) study also brings out a similar conclusion when soil quality variable is added on the productivity analysis across farms and regions. Gollin (2018, p.2) in paper cited the studies by scholars viz. Benjamin (1995), Mundlak (2000), Ghatak (2003), Gourlay et al. (2017), and Desiere et.al. (2018) who have rejected the inverse linkage between farm size and productivity. However, according to Chand (2011), in the inverse association between these variables still exist and is very well "alive"(Helfand and Taylor, 2017).

In order to assess this debate in case of our sampled villages, data has been analysed across all land size categories and villages with reference to wheat and sugarcane production. In Table 5.1 village and landholding wise the scenario of total quantity, average quantity, standard deviation in production, minimum and maximum production of wheat in sampled villages has been presented. In Gurana, the small landholders produce the highest amount of wheat i.e. 506 quintals followed by marginal (453 quintals), medium (364.5 quintals) and large farmers producing 150 quintals in one season. In Vazidpur, small farmers produce the most followed by medium category landholders, marginal and large farmers. In Pura Mahadev, marginal farmers produce 462 quintals and medium category farmers produce a total of 185 quintals trailed by small and large category landholders. In Mawi Kalan, medium category farmers take the lead in production with 635 quintals per season followed by small and marginal farmers. As far as mean production is considered, it increases with increase in landholding size i.e. large category farmers on an average produce more. Output is low on smallholdings despite higher productivity due to lower per capita availability of land. However, if we sum up the total production of wheat in each village and calculate the share of each land size category, it is found that together small and marginal farmers produce 65.08 percent of wheat in Gurana, 65.17 percent in Vazidpur, 74.45 percent in Pura Mahadev and 65.35 in Mawi Kalan. Thus, confirming the general theory that small farmers are necessary for food security and their contribution in production is the most significant in all the sampled villages. Major output comes from their side revealing that despite being refrained from all resources they produce in large quantity and contribute towards satiating the food demand of the economy.

Further, assessing village wise total production of wheat, data reveals that it is highest for Mawi Kalan followed by Gurana, Vazidpur and Pura Mahadev. The average production of wheat also showcases a similar trend.

Table 5.1: Village and Landholding Size wise Total, Average, SD, Minimum and Maximum Production of Wheat (in quintals)

	Marginal	Small	Medium	Large
GURANA				
Total	453	506	364.5	150
Mean	13.32	25.3	60.75	75
SD[1]	8.12	16.32	69.51	35.35
MIN[2]	3	10	12	50
MAX[3]	40	72	200	100
VAZIDPUR				
Total	396	466	444.5	16
Mean	12	29.12	55.56	16
SD	12.18	26.67	61.62	
MIN	2	10	12	16
MAX	70	120	200	16
PURA MAHADEV				
Total	462	121	185	15
Mean	11.55	13.44	26.42	15
SD	6.05	5.19	9.88	
MIN	4	9	15	15
MAX	30	24	40	15
MAWI KALAN				
Total	575.5	622.5	635	NA

[1] SD=Standard Deviation
[2] MIN= Minimum
[3] MAX= Maximum

Mean	14.75	31.12	63.5	NA
SD	6.78	15.79	21.47	NA
MIN	6	10	35	NA
MAX	36	54	105	NA
ALL VILLAGES				
Total	1886.5	1715.5	1629	181
Mean	10.65	21.71	40.75	45.25
SD	9.11	19.87	45.62	39.96
MIN	2	9	12	15
MAX	70	120	200	100

Source- Estimated from Field Survey Data; Note: NA denotes Not Available

Table 5.2 presents the picture of average, standard deviation, minimum and maximum productivity of wheat among different land size categories in sampled villages. In Gurana, the small landholders are highly productive i.e. produce 22 quintals per acre followed by medium (19quintals/acre), marginal (18.83quintals/ acre) and large farmers (16.25 quintals/acre). In Vazidpur, marginal farmer's productivity is highest followed by medium, small and large farmers. In Pura Mahadev, medium farmers produce 17.06 quintals/acres and marginal category farmers trail them at a productivity of 16.79 quintals /acre. In Mawi Kalan, marginal category farmers take the lead in productivity with 18.18 quintals/acre per season followed by small and medium farmers. The aggregate picture shows that average productivity is highest in marginal farms followed by small, medium and large farms. This suggests that marginal and small farmers are more productive than large farms. The inverse relationship between farm size and productivity hold true in our case.

Further, analysing productivity levels of wheat village wise, it is observed that in marginal farm size group average productivity is highest in Vazidpur (21.98 quintals/acre) while it is lowest in Pura Mahadev (16.79 quintals/acre). A similar picture is seen in case of small farm size category while in medium category Vazidpur leads but the lowest rung is replaced by Mawi Kalan. Thus, depicting higher levels of productivity in Vazidpur and Gurana.

Table 5.2: Village and Landholding Size wise Average, SD, Minimum and Maximum Productivity of Wheat (quintals/acre)

	Marginal	Small	Medium	Large
GURANA				
Mean	18.83	22.15	19.58	16.25
SD	9.08	13.67	3.32	5.30
MIN	10	14	15	12.5
MAX	66.66	75	25	20
VAZIDPUR				
Mean	21.98	19.20	21.83	16
SD	18.62	4.85	12.74	-
MIN	7.5	14	15	16
MAX	116.6	33.33	52.14	16
PURA MAHADEV				
Mean	16.79	15.83	17.06	15
SD	3.40	4.33	2.58	
MIN	10	10	15	15
MAX	25	25	20	15
MAWI KALAN				
Mean	18.18	16.25	13.38	NA
SD	3.18	2.5	4.57	NA
MIN	11.42	10	10	NA
MAX	25	20	20	NA
ALL VILLAGES				
Mean	18.81	18.73	17.59	15.87
SD	10.22	8.49	7.67	3.11
MIN	7.5	10	10	12.5
MAX	116.66	75	52.14	20

Source- Estimated from Field Survey Data; Note: NA denotes Not Available

Table 5.3 presents the total quantity, average quantity, standard deviation in production, minimum and maximum production of sugarcane among different land size categories in sampled villages. In Gurana, the marginal landholders produce the highest amount of sugarcane i.e. 22975 quintals followed by small (21415 quintals), medium (11610 quintals) and large farmers producing 8050 quintals in one season. In Vazidpur, medium farmers produce the most followed by small category landholders, marginal and large farmers. In Pura Mahadev, marginal farmers produce 19917 quintals and medium category farmers produce a total of 18725 quintals trailed by small and large category landholders. In Mawi Kalan, marginal category farmers take the lead in production with 19340 quintals per season followed by medium and small farmers. As far as mean production is considered, it increases with increase in landholding size i.e. large category farmers on an average produce more. However, overall we see that small and marginal farmers produce major portion of total production in all the sampled villages. The share of marginal and small farmers jointly is 69.30 percent in Gurana, 57.44 percent in Vazidpur, 60.29 percent in Pura Mahadev and 64.10 percent in Mawi Kalan. Considering variations in sugarcane production, data reveals that it is least in case of marginal farmers and highest in case of medium and small farmers in all sampled villages. It is mainly because of the differentials within each farm size category and also due to the fact that few medium/large farmers use the entire available land for production of sugarcane and not engage in inter-cropping. Taking into account total production land size wise and village wise, data suggests that marginal and small farmers' proportion is higher than that of medium and large farmers. Village wise analysis shows that production of sugarcane is highest in Gurana followed by Vazidpur, Pura Mahadev and Mawi Kalan.

Table 5.3: Village and Landholding Size wise Total, Average, SD, Minimum and Maximum Production of Sugarcane (in quintals)

	Marginal	Small	Medium	Large
GURANA				
Total	22975	21415	11610	8050
Mean	522.159	973.409	1935	4025
SD	291.1293	568.7693	572.8438	742.4621
MIN	110	120	1000	3500
MAX	1500	2000	2560	4550
VAZIDPUR				
Total	15837.5	16640	20205	3850
Mean	406.09	832	1554.23	3850
SD	325.1046	523.1846	668.4648	NA
MIN	70	70	70	3850
MAX	1500	1820	2560	3850
PURA MAHADEV				
Total	19917	13945	18725	3575
Mean	442.6	820.294	1702.27	3575
SD	257.6998	381.5203	430.618	NA
MIN	70	150	1000	3575
MAX	1300	1950	2600	3575
MAWI KALAN				
Total	19340	14050	18700	NA

Mean	471.707	702.5	1870	NA
SD	266.4386	220.8327	459.5892	NA
MIN	80	420	1000	NA
MAX	960	910	2100	NA
ALL VILLAGES				
Total	78069.5	66050	69240	15475
Mean	441.07	836.07	1731	3868.75
SD	295.36	453.27	295.36	478.44
MIN	70	70	70	3500
MAX	1500	2000	2600	4550

Source- Estimated from Field Survey Data; Note: NA denotes Not Available

Table 5.4 presents the scenario of average, standard deviation, minimum and maximum productivity of sugarcane among different land size categories in sampled villages. In Gurana, the marginal landholders are highly productive i.e. on an average produce 411.25 quintals per acre followed by small (358.18 quintals/acre), large (350 quintals/acre) and medium (345.51quintals/ acres. In Vazidpur, marginal farmer's productivity is highest followed by large, medium and small farmers. In Pura Mahadev, medium farmers produce 341.23 quintals/acres trailed by marginal category farmers (326.01 quintals/acre). In Mawi Kalan, marginal category farmers take the lead in productivity with 335.56 quintals/acre per season followed by small and medium farmers. This suggests that marginal and small farmers are more productive than large farms except in case of Pura Mahadev where medium farmers hold the first position. However, as three out of four villages exhibit a trend of marginal farmers being more productive, we accept this proposition that their exist the inverse relationship between farm size and productivity even in case of sugarcane .Analysing productivity levels of sugarcane village wise, it is observed that in marginal farm size group average productivity is highest in Gurana (411.25 quintals/acre) while it is lowest in Pura Mahadev (326.01 quintals/acre). In other farm size groups, Gurana village leads but the average productivity is lowest in Vazidpur. Thus, depicting higher levels of productivity in Gurana. Any single factor in isolation cannot be considered as the reason for higher productivity levels in Gurana in comparison to other villages. Better socio-economic conditions, resource use efficiency, hydrogeological conditions, productivity of labour are few possible factors.

Table 5.4: Village and Landholding Size wise Average, SD, Minimum and Maximum Productivity of Sugarcane (quintals/acre)

	Marginal	Small	Medium	Large
GURANA				
Mean	411.25	358.18	345.51	350
SD	182.53	133.68	53.83	NA
MIN	250	27.27	265.95	350
MAX	1250	800	400	350
VAZIDPUR				
Mean	354.10	265.01	282.46	350
SD	105.54	111.77	113.35	NA
MIN	71.42	18.42	14	350
MAX	787.5	350	400	350
PURA MAHADEV				
Mean	326.01	290.85	341.23	325
SD	71.53	79.27	116.36	NA
MIN	100	50	178.57	325
MAX	650	443.18	650	325
MAWI KALAN				
Mean	335.56	331.91	285.71	NA
SD	68.40	25.53	64.50	NA
MIN	225	288.88	178.57	NA
MAX	600	350	400	NA
ALL VILLAGES				
Mean	357	313.45	308.89	343.75
SD	121.01	103.28	121.01	12.5
MIN	71.42	18.42	14	325
MAX	1250	800	650	350

Source- Estimated from Field Survey Data; Note: NA denotes Not Available

Indian wheat production and its Minimum Support Price (MSP) both have steadily risen over the years. The GOI establishes a MSP for wheat and various others crops on the recommendations of the Commission for Agricultural Costs and Prices (CACP). On February 1, 2018, the GOI announced its intention to ensure that MSP would be at least 1.5 times the cost of production. Due to the government's effective MSP wheat procurement program in major growing states, market prices during the harvest season are relatively stable compared to other crops. In Krishnamurthy's (2012, p.4) paper, data has been presented on the MSP of wheat since 2006-07 till 2011-12. The MSP for wheat was 850 per quintal in 2006-07 which rose to Rs. 1285 in 2011-12. As per current data, it is Rs.1735 during 2018-19 and Rs. 1840 in 2019-20 (GOI, 2019). The farmer has two markets for selling his produce, i.e., the open market at the open market prices and government procurement agencies at the MSP. According to Niti Aayog report (2016) it has been stated that in Uttar Pradesh, all the farmers were aware of MSP but none of them knew it before the sowing season, though according to the government functionaries the declaration was done before the sowing season. All the functionaries surveyed involved in the implementation of MSP and the knowledgeable persons were in favour of continuation of MSP which indicates that in spite of all the lacunae in the process of implementation of MSP, people on the whole have benefitted from it. The wholesale market price for wheat has been higher than the MSP during the reference period, while in the case of paddy, it has been lower in Uttar Pradesh. In case of our reference villages, the price of wheat at which farmers sold their produce varied from Rs. 1735 (the MSP) to Rs.1750. The scenario of total value, average, maximum and minimum value has been presented in table 5.5 and the sale trends of wheat have been showcased in table 5.6. Table 5.5 presents the scenario of total value, average, standard deviation, minimum and maximum value of wheat among different land size categories in sampled villages. Considering marginal landholder category in all the villages it could be seen that the average total value is highest Mawi Kalan i.e. Rs. 25633.5 while lowest in Pura Mahadev. A similar picture is seen in case of all other farm size groups viz. small and medium. The reason for this hierarchy of Mawi Kalan is due to high production of wheat in this area. Referring to table 5.1 over here, we may see that the total production of wheat is highest in Mawi Kalan followed by Gurana, Vazidpur and Pura Mahadev.

Table 5.5: Village and Landholding Size wise Total, Average, SD, Minimum and Maximum of Total Value of Wheat (in Rupees)

	Marginal	Small	Medium	Large
GURANA				
Total	777435	904710	504500	260250
Mean	22865.7	45235.5	84083.3	130125
SD	14439.63	45409.35	99052.6	61341.51
MIN	5250	10350	12750	86750
MAX	72000	207000	280000	173500
VAZIDPUR				
Total	800795	844735	578625	26025
Mean	24266.5	52795.9	72328.1	26025
SD	24539.04	49580.56	86673.42	NA
MIN	3500	10350	12750	26025
MAX	122500	207000	280000	26025

PURA MAHADEV				
Total	802110	209935	307575	26025
Mean	20052.8	23326.1	43939.3	26025
SD	10525.07	9019.961	14640.11	NA
MIN	6940	15615	26025	26025
MAX	52050	41640	60725	26025
MAWI KALAN				
Total	999707	1080034	1088325	NA
Mean	25633.5	54001.7	108833	NA
SD	11789.12	27399.18	39092.86	NA
MIN	10410	17350	56000	NA
MAX	62460	93690	182175	NA
ALL VILLAGES				
Total	3380047	3039414	2479025	312300
Mean	19096	38473.6	61975.6	78075
SD	16876.01	39673.86	67799.64	69760.52
MIN	3500	10350	12750	26025
MAX	122500	207000	280000	173500

Source- Estimated from Field Survey Data; Note: NA denotes Not Available

The total sale of wheat is highest in Mawi Kalan i.e. Rs.3036881 followed by Pura Mahadev (Rs.2162885), Gurana (Rs. 14, 12,720) and Vazidpur (Rs. 994635). Households in these villages mainly earn by selling sugarcane and store wheat to fulfill their own food requirement. However, when the earning from sale of sugarcane and other farm/non farm activities is insufficient to meet the demands of household they resort to more and more sale of wheat. Table 5.6 shows the average, standard deviation, minimum, maximum and total sale in each farm size category in all the sampled villages. In Gurana, the average sale of wheat by small and marginal category farmer is Rs. 24881.9 and 46439.51 respectively while the total sales by medium category landholders is Rs.18389.31 and Rs.55207.36. The mean sales in Vazidpur are highest in case of small farmers, followed by medium and marginal category. In Pura Mahadev village, large farmer takes the lead trailed by medium, small and marginal landholder. In Mawi Kalan, the average sales are highest in the category of medium farmers and lowest in marginal farmer.

Table 5.6: Village and Landholding Size wise Total, Average, SD, Minimum and Maximum Sale Value of Wheat (in Rupees)

	Marginal	Small	Medium	Large
GURANA				
Total	447875	557270	156000	251575
Mean	24881.9	46439.2	39000	125788
SD	10972.24	43301.51	18389.31	55207.36
MIN	8750	17350	17500	86750
MAX	43375	172500	56000	164825
VAZIDPUR				
Total	419720	370815	204100	NA
Mean	26232.5	61802.5	40820	NA
SD	28737.39	58850.84	16198.33	NA
MIN	6940	17350	17500	NA
MAX	122500	172500	52500	NA
PURA MAHADEV				
Total	526920	180440	255525	1200000
Mean	21955	22555	51105	1200000
SD	9876.729	9227.479	9841.437	NA
MIN	6940	15615	34700	1200000
MAX	52050	41640	60725	1200000
MAWI KALAN				
Total	906692	1041864	1088325	NA
Mean	25185.9	52093.2	108833	NA
SD	11389.56	27650.42	39092.86	NA
MIN	10410	17350	56000	NA
MAX	62460	93690	182175	NA
ALL VILLAGES				
Total	2301207	2150389	1703950	251575
Mean	13001.2	27220.1	42598.8	62893.8
SD	16490.08	36103.7	47915.17	79310.25
MIN	6940	15615	17500	86750
MAX	122500	172500	182175	164825

Source- Estimated from Field Survey Data
Note: NA denotes Not Available

The key observations about this table cannot be made unless we throw a glimpse on table 5. 5 which show the total estimated value of wheat production amongst all land size categories in all villages. After analysis both the tables we found two interesting things 1) This scenario depicts that small/marginal farmers sell a larger chunk of their production as they are unable to earn it through other sources; 2) Village wise analysis shows that households earning in Mawi Kalan and Pura Mahadev from sale of sugarcane and other farm/non farm activities is insufficient to meet the demands of household so they resort to more and more sale of wheat.

Considering sugarcane now, we know that Uttar Pradesh is the largest producer followed by Maharashtra. The production of sugarcane has risen continuously. The GOI establishes a minimum support price (MSP) or Fair Remunerative Price (FRP) for sugarcane based on recommendations from the Commission for Agricultural Costs and Prices (CACP) in consultations with state governments and other stakeholders. Until 1970s the price fixed as per MSP was the ultimate price regulation stick but with coming up of State Advisory Price (SAP) its importance reduced. The SAP system enables state governments to fix a price for sugarcane as per their own discretion. The state governments usually keep the SAP higher than the FRP so as to maintain or gain political support from farmer community. According to CACP (2014), the higher SAP by some State Governments compared to the Central Government fixed FRP has led to increasing sugarcane arrears (CACP, 2014, p.12). The absorption capacity of the mills in the respective states and state's own production would indicate the shortfall and excess supply of sugarcane. It is also observed that with the decline in sugarcane production, the price difference is reduced. A forecast of a smaller cane crop normally encourages millers to pay higher cane prices, resulting in prices which exceed the MSP/FRP in most of the growing states. Table 5.7 presents the scenario of total value, average, standard deviation, minimum and maximum value of sugarcane among different land size categories in sampled villages. In these villages the price of sugarcane realised by farmers range within Rs.300-350 per quintal.

Considering marginal landholder category in all the villages it could be seen that the average total value is highest Gurana i.e. Rs. 163316 while lowest in Vazidpur. In small farm size group, the average total value is highest in Mawi Kalan (Rs.227773) and the lower most in Vazidpur (Rs.210888). A similar picture is seen in case of medium landholder category while in large farmer group Gurana takes the lead. The reason for this hierarchy of type of differentials with reference to different categories and villages is due to the production and rate variations.

Table 5.7: Village and Landholding Size wise Total, Average, SD, Minimum and Maximum Value of Sugarcane (in Rupees)

	Marginal	Small	Medium	Large
GURANA				
Total	6859275	5121925	3190950	2600000
Mean	163316	232815	531825	1300000
SD	94669.22	186429	309142.8	282842.7
MIN	24750	37800	22050	1100000
MAX	472500	610000	812500	1500000
VAZIDPUR				
Total	4291525	4217750	6521325	1200000
Mean	110039	210888	501640	1200000
SD	104994.7	166455	215720.6	NA
MIN	13000	1000	22050	1200000
MAX	472500	591500	812500	1200000
PURA MAHADEV				
Total	6090287	4721725	6085625	1200000
Mean	135340	277749	553239	NA
SD	73478.64	111230.7	139950.8	NA
MIN	22050	136500	325000	1200000
MAX	312000	633750	845000	1200000
MAWI KALAN				
Total	6235000	4555450	6077500	NA
Mean	152073	227773	607750	NA
SD	86442.51	72206.84	149366.5	NA
MIN	26000	136500	325000	NA
MAX	312000	295750	682500	NA
ALL VILLAGES				
Total	23476087	18616850	21875400	5000000
Mean	132633.26	235656.33	546885	1250000
SD	94568.49	143094.83	196010.77	173205.08
MIN	13000	1000	22050	1100000
MAX	4725000	633750	845000	1500000

Source- Estimated from Field Survey Data

Note: NA denotes Not Available

The total sale of sugarcane (refer table 5.8) is highest by marginal landholders in Gurana followed by small, medium and large category. The average sales done by marginal farmers is Rs.163316, small farmers is Rs.232815, medium is Rs.531825 and large is Rs. 1300000.The maximum sale value is obviously highest in case of large farmer and minimum sale value is

Rs.1000 in case of small land operator. In Vazidpur the mean sales is highest in case of medium farmer followed by small and marginal. In Pura Mahadev and Mawi Kalan also the medium category landholder leads with reference to average sale value.

Table 5.8: Village and Landholding Size wise Total, Average, SD, Minimum and Maximum Sale Value of Sugarcane (in Rupees)

	Marginal	Small	Medium	Large
GURANA				
Total	6859275	5121925	3190950	2600000
Mean	163316	232815	531825	1300000
SD	94669.22	186429	309142.8	282842.7
MIN	24750	37800	22050	1100000
MAX	472500	610000	812500	1500000
VAZIDPUR				
Total	4209625	4627250	6521325	1200000
Mean	107939	231363	501640	1200000
SD	106197.7	167278.4	215720.6	NA
MIN	9100	1000	22050	1200000
MAX	472500	591500	812500	1200000
PURA MAHADEV				
Total	6008387	4721725	6085625	1200000
Mean	133520	277749	553239	1200000
SD	75585.93	111230.7	139950.8	NA
MIN	9100	136500	325000	1200000
MAX	312000	633750	845000	1200000
MAWI KALAN				
Total	6235000	4555450	6077500	NA
Mean	152073	227773	607750	NA
SD	86442.51	72206.84	149366.5	NA
MIN	26000	136500	325000	NA
MAX	312000	295750	682500	NA
ALL VILLAGES				
Total	23312287	19026350	21875400	5000000
Mean	131707.84	240839.87	546885	1250000
SD	95373.25	142699.95	196010.77	173205.08
MIN	9100	1000	22050	1100000
MAX	472500	633750	845000	1500000

Source- Estimated from Field Survey Data

Note: NA denotes Not Available

After analysing both the above tables we may state that majority of the households amongst all landownership category in all the villages sell their sugarcane production to private or public sugar mills as it is their primary source of income. The total sales among all the villages are highest in Pura Mahadev followed by Gurana, Mawi Kalan and Vazidpur. Cultivation of sugarcane is far more profitable for the farmers in this region as the cost of cultivation and effort is less and production is significantly high. In addition, storage of wheat is necessary as it is the staple diet and cultivating on their own fields is relatively cheaper and a healthy option for them as compared to purchasing it from the market.

5.2.2. Cost of Cultivation

Cultivation of two or more crops on the same piece of land has been a well established practice in India's farming system. The significance of such cropping systems is viewed beneficial as blending of farm activities prompts expansion or specialization in agribusiness. It has significance both from the perspective of individual farmer and the country in general. Inter-cropping aids in producing a mix of harvests which can be developed on restricted land zone with the limited amount of labour, capital and other resources. There is largely an absence of information on expenses and returns with reference to different cropping systems both at provincial and national levels. Thus, our study tries to address this gap by estimating the cost of cultivation under sugarcane based cropping system in all the sampled villages.

Cost of cultivation refers to the total expenses incurred in cultivating one acre/hectare of land in production of a particular crop. It is calculated while taking into account all ABC cost measures[4]as specified by the Government of India. All types of appropriations and imputations of various costs are taken as per the guidelines given in the manual. Raghavan (2008, p.208) stated that not all items of costs have increased at the same pace. While fixed costs seemed to exhibit a gradual deceleration, operational costs have continued their relentless acceleration. In our study, we have attempted to calculate the cost of cultivation under sugarcane + wheat cropping system among different farm size categories in all sampled villages. Similar type of study has been conducted by Shinde et.al. (2009, p. 820) in Karnataka region, Kumara et.al

[4]**Cost A1** – It includes all actual expenses in cash and kind in production by the owner farmer: i) Value of hired human labour ii) Value of hired bullock labour iii) Value of machine labour, owned and hired iv) Value of owned bullock labour v) Value of owned machinery vi) Value of hired machinery vii) Value of seed viii) Value of insecticides and pesticides ix) Value of manure, fertilizers x) Depreciation of implements and machinery xi) Irrigation charges xii) Land revenue xiii) Interest on working capital xiv) Misc. expenses ;**Cost A2**: Cost A1 + rent paid for leased-in land. **Cost B**: Cost A2 + rental value of owned land (net of land revenue) & interest on owned fixed capital excluding land. **Cost C:** Cost B + imputed value of family labour

(2012, p.4) and Singh and Singh (2008, p.109.). The Baghpat district is a major sugarcane producing area cultivating early and mid late varieties of sugarcane. The sugarcane crop takes almost 12-18 months so as to generate income through its sale, there exist a need to diversify the cropping pattern i.e. grow either in sequence or opt for inter cropping. The most common sugarcane based cropping method in this region is sugarcane and wheat. Although there are many patterns but production of wheat is found to more viable among farmers due to two reasons, firstly, its high support and market price. Secondly, wheat is the staple diet of people in North India. According to ICAR Technical bulletin (2017, p.2), "the inclusion of short duration, high value crops in sugarcane based production system as inter-and/or sequential crops holds great promise in increasing efficiency, reducing the production cost, economizing the use of land and market purchased inputs".

In our study, few changes have been made to estimate the cost of cultivation so as to make it more simple and easy to calculate. We have broadly categorised the cost into two categories wherein Cost A includes all the basic expenses incurred by the farmer during a year while the Cost B is a summation of Cost A and imputed cost of family labour. For simplicity purposes, we have excluded the rental value of land and the interest on working capital.

The Cost A includes operational costs, material costs and other costs in crop production. In operational costs, the cost of hiring human labour, machine power, bullock charges have been estimated by the prevailing rate at that particular period of time in the study area. Hired labour charge at the actual wage paid in cash and other kind of payments were also converted into monetary terms at the prevailing price. Imputed value of the family labour was also calculated using the prevailing wage rate in the study area. In case of bullock, tractor and other machinery and hiring charges were applied to these as the cost for those who don't own them, whereas the cost of fuel, repairing and maintenance cost were calculated for those who own them. In case of material costs; cost of seeds, manure, chemicals, fertilizers, irrigation expenses, water charges were calculated at prevailing price at the time of application per acre basis for different categories of farmers. Other expenses include transportation, handling charges etc. Depreciation was calculated at the rate of 10 percent per annum for a life span of 12 years.

Cost A= Cost on seeds + fertilizers + hired human labour+animal labour+ irrigation charges + water charges + rent on land + repair of irrigation and other machinery + depreciation + other expenses

Cost B = Cost A + Imputed value of family labour

Seeds

The seed cost includes values of farm-saved, freely-exchanged and purchased seeds. It is estimated that hardly one-third of the Rabi farmers resort to replacement of seeds every year. The purchased seeds constitute 20-28 per cent in Madhya Pradesh and Rajasthan, and 46-53 per cent in Punjab, Haryana and Uttar Pradesh. Over 80 per cent of the farmers depend on farm-saved seeds. A number of farmers also freely exchange their home-saved seeds (Bhalla, 2006, p.2). With the seed corporations in the state and central sectors becoming redundant, farmers depend predominantly on private seed companies for commercial purchase of seeds. As these seeds are costlier (quite often reportedly spurious), requiring repeat sowings, the actual cost of cultivation on account of purchased seeds could be higher than what the comprehensive scheme reports. Despite this being one of the major reasons for the recent farm crisis, seed costs given in the comprehensive scheme have registered one of the lowest increases during the post-reform period. As per Ahirwar et.al. (2014, p.83), the cost of seeds goes on increasing with farm size.

Fertilizers and Pesticides

Six crops (rice, wheat, cotton, sugar cane, rapeseed and mustard) consume about two-thirds of the fertilizer applied. The Government of India fixes minimum support prices for the main crops, controls the farm price of urea and issues indicative selling prices of other fertilizers. The prices of fertilizers are subsidized. The Government's aim is that farmers should receive a price for their crops and pay a price for fertilizers that make the use of fertilizers acceptable and remunerative. The subsidy on fertilizers is channeled through the fertilizer production industry, being calculated to ensure a reasonable return to the industry. Fertilizer distribution is effected through private channels, cooperatives and certain institutions. The central government provides huge subsidies on fertilizers so as to boost food production and ensure food security. Sugarcane, wheat, cotton and paddy are again the crops that benefit the most from fertilizer subsidy received per hectare crop area (Praveen et.al, 2017, p.24). As far as cost of cultivation is considered, fertilizer charges account for the one of the major shareholder in the operational costs of cultivation. According to Raghavan (2008, p.123), fertilizers is an important component contributing towards enhancing productivity therefore there is a "tendency among farmers to go on increasing the application of chemical fertilizers (along with high-yielding seeds), unmindful of the accompanying problems". The use of fertilizers has increased immensely since the green revolution especially in Punjab, Haryana and Uttar Pradesh. As government distribution network of fertilizers/ insecticides/ pesticides is weak several private shops have opened up and they sell it at high price which has elevated the cost of cultivation.

Irrigation and Water Charges

The cost of irrigation is dependent on the sources of irrigation, like surface water, wells, tube-wells, tanks and so on. It also depends on prices of pump sets, low speed diesel oil, electricity tariffs, canal irrigation rates, etc. In terms of importance, there are two major irrigation sources. Water from wells and tube-wells drawn with electricity and diesel pump sets work out to around 70 per cent of all sources in Haryana and Uttar Pradesh and as high as 97 per cent in Punjab. The next major source of irrigation is surface water from rivers, springs or canals. Compared to pump irrigation, the share of flow irrigation is rather insignificant, except in Madhya Pradesh, where it comes to about one-fourth of all sources of irrigation. According to Kumar (2011, p.270) in his study stated that it the scarcity value of water is not felt by the farmers because agriculture sector lacks effective water and energy pricing. Due to such norms and unregulated water abstraction is being done and farmers have no incentive to use water saving techniques on farms. Small and marginal farmers who lack ownership of submersibles/ diesel pumpsets etc. purchase water from other famers (majorly large and medium farmers) at a price decided by the water sellers. "These farmers are confronted with positive marginal cost of using water, and have incentive to use water efficiently" (Kumar et al., 2010, p.270; Kumar et al., 2011, p.382). However, in areas of the country under extreme water stress, farmers use water efficiently as they "are confronted with opportunity cost of using water". Due to these reasons, they practice sustainable and effective use of water which indirectly increase returns from farming.

Hired Labour

Indian agriculture sector is witnessing major changes. The FICCI Report (2015, p.2) entitled "Labour in India Agriculture: A Growing Challenge" mentioned that a general trend has been observed all across the globe that when a particular country is on a path of economic progress the workforce tends to move globe from primary sectors of the economy. "Consistent with this empirical evidence observed worldwide, even in India, the percentage of people employed in agriculture has been consistently declining, from around 60 percent in 1999-00 to 49 percent in 2011-12". The young generation living in rural areas does not want to work on farm and rushing to nearby urban areas for employment. This has promoted hiring of labourers to work on farms. Males and females both are being hired as labourers though wage differentials still exist. According to Narayanamoorthy (2007, p.2375), the cost of cultivation has risen over the years due to the fact that earlier the family members performed all the duties on farm and no remuneration has to be given but now with nuclear families, male migration and other employment opportunities demand for hired labours has risen which has also raised the overall wage levels. According to Chavan and Bedamatta (2006, p.23) there has been a slowdown in the rate of growth of wages but the differences between the average wages of male and female agricultural labourers have widened over the years.

Family Labour

The importance of family labour in Indian agriculture setup is not unknown. Factors such as higher remuneration and growth of opportunities in alternate sectors coupled with the relatively lower rise in wages in agricultural occupations as compared to other sectors have led to the migration of workforce away from agriculture which has resulted in labour shortage and consequent escalation of cost of cultivation. The family members who are able to get better job and remuneration and job outside are opting for it and leaving the family occupation. Currently, it is the females in agriculture sector who are serving as unpaid labourers and performing all duties on and off farm. As per NSSO round (2011-12) 43.8 percent women under principal status worked as unpaid family labor while 60.3 percent under subsidiary status in rural areas of the country (Sanghi et.al, 2015, p.255). Chakravorty (1975, p.50) found that an active farm woman spends around 8 to 9 hours on the farm during the peak agricultural season, 3 to 4 hours on taking care of the cattle and 3 to 4 hours on their household chores. According to Agarwal (1983, p.22) women devoted 17 percent, 68 percent and 15 percent of their work time to agriculture, animal husbandry and supportive activities respectively. Singh and Bhati (1985, p.11) point out that on an average, a female worker devoted 4.2 hours of work per day on marginal farms, 4.1 hours on small farms and 3.6 hours on medium size farms. Ghosh (2014, p.2) stated in his working paper that engagement and participation of women workers is present in almost all activities of agriculture but there is discrimination in wages even if they do same type of work as male labour. Further despite of their extensive and active involvement in agriculture of India, they are not considered for decision making in farm activities.

Electricity

According to World Bank Report (2001) providing highly subsidized but poor quality power to agriculture is an impediment to agricultural growth and income. Due to the erratic electric power, farmers' costs particularly in the purchase of unnecessarily high-powered electric pumps and back-up or alternate diesel pumps and in the repair of pumps that burn out are notably higher than they would be if supply were reliable and voltage steady. Corollary costs flow from the time lost repairing equipment and the timeliness lost in getting water to crops when it is most needed. According to Kaur (2012, p.40), power subsidies majorly benefits large farmers who use groundwater for irrigation compared to small farmers. Mirroring this, the present pricing regime based on a flat rate structure results in higher electricity prices for the small farmers compared to large farmers because of their lower level of consumption. The electricity subsidy exclusively benefits electric pump owning farmers, especially the medium to large farmers, as they predominantly own the electric pumps and account for the larger share of electricity consumption. In addition to this, the fiscal cost associated with the provision of this large subsidy is very large at 1.2-1.5 % of GSDP in Haryana and Andhra Pradesh, creates other distortions and sacrifices elsewhere in the economy. Further, electricity consumption by farmers is estimated to be much lower than what officially attributed. This implies that theft and losses are much higher than earlier estimated. The state subsidies to agriculture, which are assumed to help the poor farmers, are in fact benefiting mainly better off farmers and thieves of power. Over the medium term, farmers' income, would increase if quality of power supply was improved partially financed through higher tariffs.

An aggregate picture of cost of cultivation across all land size categories is presented in table 5.9. The net return from cultivation goes on increasing with farm size, it is highest for large farmers (Rs. 66667.66 per acre) and lowest for marginal (Rs.21634.49). Considering the total cost (Cost B), an inverse trend is witnessed i.e. it decreases with increase in farm size. The total cost of cultivation in case of marginal farmer it is Rs.80420.63 per acre which reduces to Rs.54224.05 per acre in case of small landholder and drops further to Rs. 46207.78, Rs. 46098 per acre in medium category and large farm size respectively. A similar pattern is observed in case of cost A which excludes the imputed value of family labour. The value of family labour is highest with reference to marginal landholder and goes on decreasing with increase in farm size. The value of output per acre is highest in case of large farmer (Rs.113027.7/acre) followed by marginal, medium and small category, suggesting high productivity in case of large farms. The expenditure incurred on seeds, hired labour is relatively higher in marginal farm size category than other farm sizes. The amount paid as rent on land is highest for small farmer and lowest for the marginal category farmer. In case of expenses on animal labour, marginal farmers spends Rs. 536.69 per acre whereas small category farmer pays Rs. 223.61 and medium landholder Rs.57.13 per acre. Considering other expenses, the marginal farmer shells out Rs. 1174.91 per acre while small farmer pays Rs. 465.31 per acre. Irrigation expenditure is Rs.434.93 per acre with reference to marginal farm size category while the amount is higher in case of small farmer (Rs.722.65/acre). The most significant cost aspect (as per our study), the water charges paid to farmer providing water is highest in case of marginal farmer i.e. Rs. 5015.42 per acre followed by small landholder (Rs. 2743.65 per acre), medium (Rs. 949.85 per acre) and Rs.187.65 per acre in case of large farmer. The expenditure incurred on fertilizer is relatively low for small farmers and highest for large farmers (Rs. 17234.04 per acre) but is almost same for other categories i.e. approx. Rs.15000 per acre. Depreciation accounts losses in irrigation machinery. It is lowest in case medium farmer (Rs.2791/acre) and highest with reference to marginal category (Rs.7372.09 per acre). The electricity expenditure for marginal landholder is Rs.7866.16 per acre followed by small farmer (Rs.4763.19/acre), medium (Rs.3770.83/acre) and large (Rs.3127.66/acre). The cost incurred on repair of machinery is Rs.2832.87 for marginal farmer, Rs.1852.60 for small landholder, Rs. 1721 per acre for medium category farm size and Rs.1765/acre for large farmer. The cost of diesel per acre is estimated to be highest in case of large farmer i.e. Rs.6170.23 per acre while is lowest for small landholder i.e. Rs. 4008.13 per acre. Therefore, overall we see that the cost incurred by marginal farmer is higher than the large and medium category farmers in all the villages.

Table 5.9: Land Holding Size wise Cost of Cultivation In Sampled Villages (Rs./acre)

Inputs	Marginal	Small	Medium	Large
Seeds	1041.49	869.14	546.12	517.02
Hired Labour	10365.63	7188.46	8094.28	8191.48
Land Rent	306.40	1160.46	494.35	0
Animal Labour	536.69	223.61	57.13	0
Other Exp	1174.91	465.31	515.53	0
Irrigation	434.93	722.65	165.96	0
Water Charges	5015.42	2743.65	949.85	187.65
Fertilizer	15034.40	14770.51	15000	17234.04
Depriciation	7372.04	4235.89	2791.31	2872.34
Electricity	7866.16	4763.19	3770.83	3127.66
Repair	2832.87	1852.60	1721.39	1765.95
Diesel	4383.41	4008.13	5727.40	6170.21
Cost A	56364.42	43003.67	39834.19	40066.38
Family Labour	24056.21	11220.38	6373.58	6031.91
Cost B	80420.63	54224.05	46207.78	46098.3
Gross Return	102055.12	95845.08	85516.88	112766
Net Return	21634.49	41621.04	39309.1	66667.66
Value of Output	101589.25	81593.66	85997.26	113027.7

Source- Estimated from Field Survey Data

After the brief discussion on the major components of cost of cultivation the scenario of cost pattern in *sugarcane based cropping system* across all landholding sizes in all sampled villages, inter-village assessment of cost dynamics in presented.

The net return from cultivation is goes on increasing with farm size in Gurana (table 5.10), is highest for large farmers (Rs.78451.3/acre) and lowest for marginal (Rs.35841.47/acre). Considering the total cost (Cost B), an inverse trend is witnessed i.e. it decreases with increase in farm size. The total cost of cultivation in case of marginal farmer is Rs. 77307.39 per acre which reduces to Rs.53618.26/acre in case of small landholder and drops further to Rs. 47635.65/acre, Rs. 41739.96/acre in large and medium category farm size respectively. A similar pattern is observed in case of cost A which excludes the imputed value of family labour. The value of family labour is highest with reference to marginal landholder and goes on decreasing with increase in farm size. The value of output per acre is highest in case of large farmer (Rs.124358/acre) followed by marginal, medium and small category, depicting higher productivity in terms of large farmers. The expenditure incurred on seeds, hired labour is relatively higher in marginal farm size category than other farm sizes. The amount paid as rent on land is highest for large farmer and lowest for the marginal category farmer. In case of expenses on animal labour, marginal farmers spends Rs. 639.53 per acre whereas small category farmer pays Rs. 141.57 per acre and medium landholder Rs.203.86 per acre. Considering other expenses the marginal farmer shells out Rs. 227.24/acre while small farmer pays Rs. 456.88 per acre. The medium and large farmer does not incur any expenditure on account of other expenses. Irrigation expenditure in Gurana is Rs.227 per acre with reference to marginal farm size category while the amount is higher in case of small farmer (Rs.456.8/acre). The most significant cost aspect (as per our study), the water charges paid to farmer providing water is highest in case of marginal farmer i.e. Rs. 4893.32 followed by small landholder (Rs. 2383.83/acre), medium (Rs. 1120.17/acre) and Rs.383.47/acre in case of large farmer. The expenditure incurred on fertilizer is almost same with reference to marginal, small and medium category (approx. Rs.15000/acre) but a bit higher for large farmer Rs. 19656 per acre by marginal category landholder is Rs.15129/acre. Depreciation accounts losses in irrigation machinery. It is lowest in case of medium farmer (Rs.1915/acre) and highest with reference to marginal category (Rs.5549.63/acre). The electricity expenditure for marginal landholder is Rs.5786.11 per acre followed by small farmer (Rs.4841.69/acre), large (Rs.3782.60/acre) and medium (Rs.2540.77/acre). The cost incurred on repair of machinery is Rs.1948 for marginal farmer, Rs.1981/acre for small landholder, Rs. 804/acre for medium category farm size and Rs. 1956/acre for large farmer. The cost of diesel per acre is estimated to be highest in case of marginal farmer i.e. Rs.4175 while is lowest for medium landholder i.e. Rs. 2832.61/acre. Considering imputed value of family labour, data reveals that it is highest for marginal category farmer viz. Rs. 23526.49 per acre followed by small (Rs.10379.67), medium (Rs.7886.26) and large landholder (Rs.6847.82/acre). Therefore, overall we see that the cost incurred by marginal farmer is higher than the large and medium category farmers in Gurana.

Table 5.10: Land Holding wise Cost of Cultivation in Gurana (Rs. /acre)

Items	Marginal	Small	Medium	Large
Seeds	809.82	631.27	436.30	534.78
Hired Labour	12729.73	8207.85	7379.82	8043.47
Land Rent	362.16	1853.28	1287.55	0
Animal Labour	639.53	141.57	203.86	0
Other Exp	1531.03	308.88	332.61	0
Irrigation	227.24	456.88	0	0
Water Charges	4893.32	2383.83	1120.17	383.47

Fertilizer	15129.17	14604.12	15000	19565.22
Depreciation	5549.63	4251.93	1915.23	2608.69
Electricity	5786.11	4841.69	2540.77	3782.60
Repair	1948.58	1981.98	804.72	1956.52
Diesel	4175.54	3575.29	2832.61	3913.04
Cost A	**53781.91**	**43238.6**	**33853.69**	**40787.83**
Family Labour	23526.49	10379.67	7886.266	6847.82
Cost B	**77308.39**	**53618.26**	**41739.96**	**47635.65**
Gross Return[5]	113149.9	107343.6	85536.05	126087
Net Return[6]	**35841.47**	**53725.3**	**43796.09**	**78451.3**
Value of Output[7]	**108476**	**77562.87**	**79301.5**	**124358.7**

Source- Estimated from Field Survey Data

The net return from cultivation is goes on increasing with farm size in Vazidpur (table 5.11), it is highest for large farmers (Rs.55458.33/acre) and lowest for marginal (Rs.21916.46/acre). Considering the total cost (Cost B), an inverse trend is witnessed i.e. it decreases with increase in farm size. The total cost of cultivation in case of marginal farmer is Rs. 79635.3 per acre which reduces to Rs.45169.24/acre in case of small landholder and drops further to Rs. 44541.67/acre, Rs. 43834.57/acre in large and medium category farm size respectively. A similar pattern is observed in case of cost A which excludes the imputed value of family labour. The value of family labour is highest with reference to marginal landholder and goes on decreasing with increase in farm size. The small landholders largely depend upon family members for farming purposes so that their expenditure on hiring labourers can be minimized. The value of output per acre is highest in case of large farmer (Rs.102168.8/acre) followed by marginal, medium and small category, depicting higher productivity in terms of large farmers. The expenditure incurred on seeds, hired labour is relatively higher in marginal farm size category than other farm sizes. The seed cost per acre in Vazidpur in marginal category is Rs.1291.34/acre, Rs.1216.83/acre in small farm size and reduced to Rs.500/acre in case of large landholding. The amount paid as rent on land is highest for large farmer and lowest for the marginal category farmer. In case of expenses on animal labour, marginal farmers spends Rs. 804.94 per acre whereas small category farmer pays Rs. 593.26/acre and medium landholder Rs.73.73/acre. Considering other expenses, the marginal farmer shells out Rs. 2188.39 while small farmer pays Rs. 595.85 per acre. The medium farmer spends Rs.1440.39/acre and large farmer does not incur any expenditure on

[5] Gross Returns = Sale Quantity of sugarcane +wheat*Price
[6] Net Returns = Gross Return – Cost B
[7] Value of output refers to total output*Price

account of other expenses. Irrigation expenditure in Vazidpur is Rs.779 per acre with reference to marginal farm size category followed by small (Rs.418.39/acre) and medium farmer (Rs.353.20/acre). The most significant cost aspect (as per our study), the water charges paid to farmer providing water is highest in case of marginal farmer i.e. Rs. 4463.55/acre followed by small landholder (Rs.2195.59/acre), medium (Rs. 805.73/acre). There is zero and low expenditure on irrigation and water charges in case of large and medium farmer because they have sufficient income to install a submersible pumpset on farm and fulfill their irrigation requirements. It is due to pumpset ownership that they have become water lords and provide groundwater to other farmers (small and marginal land operators) at discretionary price. The expenditure incurred on fertilizer is almost same with reference to marginal, small and medium category (approx. Rs.15000/acre). Depreciation accounts for losses in irrigation machinery. It is lowest in case of medium farmer (Rs.1788.07/acre) and highest with reference to marginal category (Rs.8527.59/acre). The electricity expenditure for marginal landholder is Rs.8333.01 per acre followed by small farmer (Rs.3489.63/acre), medium (Rs. 2511.03/acre) and large (Rs.2500/acre). The cost incurred on repair of machinery is Rs.3588.96/acre for marginal farmer, Rs.1256/acre for small landholder, Rs.1335.45/acre for medium category farm size and Rs. 1500/acre for large farmer. The cost of diesel per acre is estimated to be highest in case of large farmer i.e. Rs.8333.33/acre followed by medium and marginal and small landholders. Therefore, overall we see that the input cost incurred by marginal farmer is higher than the large and medium category farmers in Vazidpur except with reference to diesel and land rent.

Table 5.11: Land holding wise Cost of Cultivation in Vazidpur (Rs. /acre)

Items	Marginal	Small	Medium	Large
Seeds	1291.34	1216.83	566.57	500
Hired Labour	11673.83	6194.94	7344.37	8333.33
Land Rent	371.07	725.38	883.00	0
Animal Labour	804.94	593.26	73.73	0
Other Exp	2188.39	595.85	1440.39	0
Irrigation	779.82	418.39	353.20	0
Water Charges	4463.55	2195.59	805.73	0
Fertilizer	15000	14611.4	15000	15000
Depreciation	8527.59	3346.82	1788.07	3125
Electricity	8333.01	3489.63	2511.03	2500
Repair	3588.96	1256.47	1335.54	1500
Diesel	3307.32	2487.04	4558.49	8333.33

Cost A	**60329.88**	**37131.67**	**36660.18**	**39291.67**
Family Labour	19305.42	8037.565	7174.393	5250
Cost B	**79635.3**	**45169.24**	**43834.57**	**44541.67**
Gross Return	101551.8	85468.52	74232.06	100000
Net Return	**21916.46**	**40299.29**	**30397.49**	**55458.33**
Value of Output	**96904.28**	**65576.23**	**78365.89**	**102168.8**

Source- Estimated from Field Survey Data

Similar to the trend witnessed in case of Gurana and Vazidpur, the net return from cultivation is goes on increasing with farm size in Pura Mahadev (table 5.12). It is highest for large farmers (Rs.55291.67/acre) and lowest for marginal (Rs.10049.96/acre). Considering the total cost (Cost B), an inverse trend is witnessed i.e. it decreases with increase in farm size. The total cost of cultivation in case of marginal farmer is Rs. 79720.74 per acre which reduces to Rs.54899.09/acre in case of small landholder and drops further to Rs. 43881.82/acre, Rs. 44708.33/acre in medium and large category farm size respectively. A similar pattern is observed in case of cost A which excludes the imputed value of family labour. The value of family labour is highest with reference to marginal landholder and goes on diminishing as farm size increases. The small landholders largely depend upon family members for farming purposes so that their expenditure on hiring labourers can be minimized. The value of output per acre is highest in case of large farmer (Rs.102168.8/acre) followed by marginal, medium and small category, depicting higher productivity in terms of large farmers. The expenditure incurred on seeds, hired labour is relatively higher in marginal farm size category than other farm sizes. The seed cost per acre in Pura Mahadev in marginal category is Rs749.31/acre as compared to Rs.500/acre in large category landholders. The amount paid as rent on land exists only for marginal farmers and is Rs.210 per acre. Considering other expenses over here, the marginal farmer spends Rs. 646.97 while small farmer pays just Rs. 244.56 per acre. Irrigation expenditure in Pura Mahadev is Rs.728.02 per acre with reference to marginal farm size category followed by small (Rs.760.86/acre) and medium farmer (Rs.194.80). The most significant cost aspect (as per our study), the water charges paid to farmer providing water is highest in case of marginal farmer i.e. Rs. 4904.80/acre followed by small landholder (Rs.3286.59/acre), medium (Rs. 920.77/acre). There is zero and low expenditure on irrigation and water charges in case of large and medium farmer because they have sufficient income to install a submersible pumpset on farm and fulfill their irrigation requirements. The water purchasing by large and medium farmer is usually not seen, it happens only when they own or operate another land which is far from their place of main cultivation and there is no provision of submersible pumpset on that farm. Focusing on the expenditure incurred on fertilizer, it is observed that it is almost constant same with reference to all landholding sizes i.e. Rs.15000 per acre. Depreciation accounts for losses in irrigation machinery. It is lowest in case of medium farmer (Rs.2863.63/acre) and highest with reference to marginal category (Rs.7912.08/acre). The electricity expenditure for marginal landholder is Rs.8668.95 per acre followed by small farmer (Rs.4543.47/acre), medium (Rs. 3584.41/acre) and large (Rs.2500/acre). The cost incurred on repair of agricultural/irrigation machinery is Rs.3317.30/acre for marginal farmer, Rs.2351.44/acre for small landholder, Rs.2207.79/acre for medium category farm size and Rs. 1666.67/acre for large farmer. The cost of diesel per acre is estimated to be highest in case of large landholder and lowest for marginal farmers. Therefore, overall we see that the input cost incurred by marginal farmer is higher than the large and medium category farmers in Pura Mahadev except with reference to diesel and land rent.

Table 5.12: Land Holding wise Cost of Cultivation in Pura Mahadev (Rs./acre)

Items	Marginal	Small	Medium	Large
Seeds	749.31	424.09	454.54	500
Hired Labour	7836.53	7726.44	8142.85	8333.33
Land Rent	247.25	0	0	0
Animal Labour	210.85	0	0	0
Other Exp	646.97	244.56	0	0
Irrigation	728.02	760.86	194.80	0
Water Charges	4904.80	3286.59	920.77	0
Fertilizer	15000	15000	15000	15000
Depreciation	7912.08	4592.39	2863.63	3125
Electricity	8668.95	4543.47	3584.41	2500
Repair	3317.30	2351.44	2207.79	1666.66
Diesel	3598.90	3985.50	5194.80	8333.33
Cost A	**53821.02**	**42915.4**	**38563.64**	**39458.33**
Family Labouro	25899.73	11983.7	5318.18	5250
Cost B	**79720.74**	**54899.09**	**43881.82**	**44708.33**
Gross Return	89770.7	88807.34	82352.6	100000
Net Return	**10049.96**	**33908.24**	**38470.78**	**55291.67**
Value of Output	**94675.78**	**89341.67**	**83028.57**	**102168.8**

Source- Estimated from Field Survey Data

The net return from cultivation is goes on increasing with farm size in Mawi Kalan and is thereby highest for medium land size farmers (as no respondent could be found who owned a large landholding) and lowest for marginal (Rs.19146.97/acre). Considering the total cost (Cost B), an inverse trend is witnessed i.e. it decreases with increase in farm size. The total cost of cultivation in case of marginal farmer is Rs. 84959.33 per acre which reduces to Rs.67051.9/acre in case of small landholder and drops further to Rs. 54936.96/acre in medium category farm size. A similar pattern is observed in case of cost A which excludes the imputed value of family labour. The value of family labour is highest with reference to marginal landholder and goes on diminishing as farm size increases. The small landholders largely depend upon family members for farming purposes so that their expenditure on hiring labourers can be minimized. The value of output per acre is highest in case of marginal farmers (Rs.105462.2/acre) followed by medium (Rs.101907.5/acre) and small category (101907.5/acre), depicting higher productivity in terms of marginal farmers which. This phenomenon is unseen in other villages. The expenditure incurred on seeds, hired labour is relatively higher in marginal farm size category than other farm sizes. The seed cost per acre in Mawi Kalan in marginal category is Rs.1397.95/acre as compared to Rs.695.65/acre in large category landholders. The amount paid as rent is higher for small landholder than the one who owns a marginal farm land. Considering other expenses over here, the marginal farmer spends Rs. 593.29 per acre while small farmer just Rs. 723.32/acre. Irrigation expenditure in Mawi Kalan is higher for small farmer than the marginal landholder. The most significant cost aspect (as per our study), the water charges paid to farmer providing water is highest in case of marginal farmer i.e. Rs. 5680.90/acre followed by small landholder (Rs.3472.87/acre), medium (Rs. 1056.2/acre). There is zero and low expenditure on irrigation and water charges in case of large and medium farmer respectively because they have sufficient income to install a submersible pumpset on farm and fulfill their irrigation requirements. Focusing on the expenditure incurred on fertilizer, it is observed that it is almost constant same with reference to all landholding sizes i.e. Rs.15000 per acre. Depreciation accounts for losses in irrigation machinery. It is lowest in case of medium farmer (Rs.4619.56/acre) and highest with reference to marginal category (Rs.7784/acre). The electricity expenditure for marginal landholder is Rs.8791.54 per acre followed by small farmer (Rs.6650/acre) and medium (Rs. 6463.76/acre). The cost incurred on repair of agricultural/irrigation machinery is Rs.2647.23/acre for marginal farmer and Rs.2304.34/acre for medium category farm size. The cost of diesel per acre is estimated to be highest in case of large landholder and lowest for marginal farmers. Therefore, overall we see that the input cost incurred by marginal farmer is higher than the large and medium category farmers in Mawi Kalan except with reference to diesel and land rent.

Table 5.13: Land holding wise Cost of Cultivation in Mawi Kalan (Rs./acre)

Items	Marginal	Small	Medium	Large
Seeds	1397.95	1162.38	695.65	NA
Hired Labour	9620.99	6607.41	9507.24	NA
Land Rent	262.39	1952.98	0	NA
Animal Labour	571.42	46.11	0	NA
Other Exp	593.29	723.32	0	NA
Irrigation	72.88	1482.82	0	NA
Water Charges	5680.90	3472.87	1056.52	NA
Fertilizer	15000	15000	15000	NA
Depreciation	7784.25	5099.45	4619.56	NA
Electricity	8791.54	6650.99	6463.76	NA
Repair	2647.23	2005.42	2304.34	NA
Diesel	6253.64	6763.11	9811.59	NA
Cost A	**58676.53**	**50966.91**	**49458.7**	NA
Family Labour	26282.8	16084.99	5478.26	NA
Cost B	**84959.33**	**67051.9**	**54936.96**	NA
Gross Returns	104106.3	101217.3	103852.5	NA
Net Returns	**19146.97**	**34165.35**	**48915.58**	NA
Value of Output	**105462.2**	**101907.5**	**103852.5**	NA

Source- Estimated from Field Survey Data

Inter village comparison from the above tables show that the total cost of cultivation in marginal category is highest in Mawi Kalan i.e. Rs. 84959.33/acre followed by Pura Mahadev (Rs.79720.4/acre), Vazidpur (Rs.79635.3/acre) and Gurana (Rs.77308/acre). A similar trend is observed in all land size categories. Considering the net returns, data reveals that across all land size categories Gurana farmers earn the maximum profit except in case of medium landholder wherein Mawi Kalan leads and is trailed by Gurana, Pura Mahadev and Vazidpur. The probable reason for it being that the medium farmers (large farmers in real context) are so well off that socio-economic and hydrogeological profile of area does not affect them. However, small and marginal farmers are the most vulnerable group and area conditions have major influence on their farming and income pattern. Taking into account the overall inter-farm size analysis, data suggest that marginal farmers in all villages bear the highest cost of cultivation followed by small, medium and large farmers. The highest share of their expenditure is incurred on imputed value of family labour (approx. 30 percent) followed by hired labour (ranging from 10-15 percent), electricity (10 percent), fertilizers (6-9 percent). The water charges command 5-6 percent of the total cost in case of marginal and small farmers whereas medium and large farmers expenditure is just 2-1 percent of the total cost on it. The diesel and land rent are the only cost components in which medium and large farmers lead otherwise the cost is higher with reference to marginal and small landholders. Our results regarding cost of cultivation are in consistency with the opinion of several other scholars. Dev (2012, p.4) in a working paper on agriculture mentioned that usually it is found and believed that small holdings in India have higher productivity than medium and large farms but are not able to earn higher than the large landholders. He further argues that their cost of cultivation per hectare is also significantly higher than medium and large farms. As per the NSSO data realised by him, the net farm income at all India level show a trend of small and marginal farmers benefitting however in 9 out of 20 which includes Uttar Pradesh represent a reverse trend i.e. returns from farming are higher with reference to large farmers. Our data findings also confirm this proposition. The cost of cultivation is higher in case of marginal farm size group than the large farm size across all villages. The operating costs (per unit) may be lower on larger farms because of their ability to negotiate volume discounts on inputs, better management and other factors. Asset ownership costs may also be less because capital items such as machinery, buildings, and equipment are spread over more units of production (Zepeda, 1995, p.3). According to Duffy (2009, p.3), the costs are spread over in case of large farmers thereby establishing economies of size.

5.2.3. Change in Cropping Pattern

Changes in cropping pattern have been significant in Indian agriculture with climatic shifts, population pressures and globalisation. The respondents in our study were asked a simple question that whether they have or have not changed their cropping pattern in last 10 years. Table 5.14 shows that out of total 300 households, 88.33 percent agreed and only 11.67 percent denied. In Gurana, 90.67 percent agreed and 9.33 disagreed. A similar pattern was seen in almost all the villages with people in Vazidpur 92 percent agreeing and 8 percent disagreed. The percentage of people saying yes was 84 percent in Pura Mahadev and 16 percent said no. In Mawi Kalan, 86.67 percent out of the total agreed to the point that they changed the cropping pattern while others denied so.

Table 5.14: Village wise Households view on Change in Cropping Pattern

Village	Yes	No	Total
Gurana	68 90.67* 25.66**	7 9.33* 20**	75 100* 25**
Vazidpur	69 92* 26.04**	6 8* 17.14**	75 100* 25**
Pura-Mahadev	63 84* 23.77**	12 16* 34.29**	75 100* 25**
Mawi Kalan	65 86.67* 24.53**	10 13.33* 28.57**	75 100* 25**
Total	265 88.33* 100**	35 11.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note: *row percentage **column percentage; Pearson chi2(3) = 2.94 Pr = 0.40

Few years back, the farmers told that they used to grow maize, rice and other vegetables but since last ten years their cropping pattern is stick to sugarcane and wheat.

Primary Reason for Shift in Cropping Pattern

Village wise main reason for shift in cropping pattern across all villages is higher returns with more than 50 percent households stating it. In Gurana, 72 percent mentioned higher returns to production as change in cropping pattern. In Vazidpur, 58 percent stated so, similarly in Pura Mahadev (60 percent) and Mawi Kalan (73.33 percent).

Table 5.15: Village Wise Primary Reason for Shift in Cropping Pattern

Village	High productivity in crop	Higher Returns from crop sale	Less Effort By farmer	Less Water Required by crop	Peer Influence	Suitable for Climate	No Change in pattern	Total
Gurana	8 10.67* 24.24**	54 72* 27.27**	3 4* 50**	0 0* 0**	0 0* 0**	3 4* 18.75**	7 9.33* 20**	75 100* 25**
Vazidpur	9 12* 27.27**	44 58.67* 22.22**	1 1.33* 16.67**	1 1.33* 100**	6 8* 54.55**	8 10.67* 50**	6 8* 17.14**	75 100* 25**
Pura Mahadev	8 10.67* 24.24**	45 60* 22.73**	1 1.33* 16.67**	0 0* 0**	5 6.67* 45.45**	4 5.33* 25**	12 16* 34.29**	75 100* 25**
Mawi Kalan	8 10.67* 24.24**	55 73.33* 27.78**	1 1.33* 16.67**	0 0* 0**	0 0* 0**	1 1.33* 6.25**	10 13.33* 28.57**	75 100* 25**
Total	33 11* 100**	198 66* 100**	6 2* 100**	1 0.33* 100**	11 3.67* 100**	16 5.33* 100**	35 11.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage ** column percentage; Pearson chi2(18) = 27.41 Pr = 0.07

Sugarcane farming is commercially attractive so its cultivation is beneficial for the farmers in this region. They tend to get high prices of their produce from private sugarcane mills though there might be delay in payments. In addition to this, intercropping of sugarcane and wheat is economically viable and time-saving. As the geographical and hydrological conditions are favourable to sugarcane farming in this part of the country, productivity levels are higher and it is due to this reason that western Uttar Pradesh is called ‘sugar basket of India’.

5.2.4. Increase in Irrigation Expenditure

Considering the irrigation expenditure trend respondent were asked about their perception on increase in irrigation expenses. In all the villages, respondents believed that there has been significant rise in irrigation expenses over the period. With rising water stress and climate change such expenditure is expected to rise significantly.

Table 5.16: Village wise Household's view on increase in irrigation expenditure

Village	Yes	No	Total
Gurana	72 96* 25.09**	3 4* 23.08**	75 100* 25**
Vazidpur	71 94.67* 24.74**	4 5.33* 30.77**	75 100* 25**
Pura Mahadev	73 97.33* 25.44**	2 2.67* 15.38**	75 100* 25**
Mawi Kalan	71 94.67* 24.74**	4 5.33* 30.77**	75 100* 25**
Total	287 95.67* 100**	13 4.33* 100**	300 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage ** column percentage; Pearson chi2(3) = 0.88 Pr = 0.82

Considering the irrigation expenditure across various land-sizes respondents believed that there has been significant rise in irrigation expenses over the period. With climate change, less rainfall and inadequate canal infrastructure farmers have shifted to groundwater irrigation. However, over-extraction and absence of sufficient recharge has made groundwater abstraction expensive.

5.2.5. Water Purchasing is economically unviable

Rising water stress has lead to creation of groundwater markets wherein the small marginal farmers purchase water from rich farmers who own submersible pumpsets. These water sellers ask for prices from water buyers as per his choice. Across all the villages (table 5.17), famers who purchase water consider water buying phenomenon to be economically unviable as water for irrigation is a basic right and paying high amount as per different hydrological conditions. In Gurana, 20 percent do not purchase water while 74.67 percent considered water purchasing to be economically unviable. Although, water charges in Gurana ranges from Rs.40-50 per hour in this village which is relatively less than other sampled village. In Vazidpur, Pura Mahadev and Mawi Kalan also showcase a similar trend with majority of the farmers agreeing that water buying is economically unviable.

Table 5.17: Village wise Respondents view on Water Purchasing is Economically Unviable

Village	No	Yes	Do Not purchase	Total
Gurana	4 5.33* 18.18**	56 74.67* 24.89**	15 20* 28.3**	75 100* 25**
Vazidpur	13 17.33* 59.09**	48 64* 21.33**	14 18.67* 26.42**	75 100* 25**
Pura Mahadev	3 4* 13.64**	62 82.67* 27.56**	10 13.33* 18.87**	75 100* 25**
Mawi Kalan	2 2.67* 9.09**	59 78.67* 26.22**	14 18.67* 26.42**	75 100* 25**
Total	22 7.33* 100**	225 75* 100**	53 17.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage ** column percentage; Pearson chi2(6) = 17.04 Pr = 0.00

Across all land size group, famers who purchase water consider water buying phenomenon to be economically unviable as water for irrigation is a basic right and paying high amount as per different hydrological conditions.

5.2.6. Credit Facility

There has been a rise in credit availability in Indian agriculture. In our study we posed a question to the respondent on credit taken from commercial banks. In Gurana (table 5.18), 53.33 percent farmers responded positively while 46.67 percent did not. In Vazidpur, 56 percent availed credit facility while the percentage of farmers taking loans for agricultural purposes was high in Pura Mahadev (80 percent) and Mawi Kalan (85.33 percent). This trend shows that farmers in Pura Mahadev and Mawi Kalan are largely dependent on credit for fulfilling their agricultural demands.

Table 5.18: Village wise Loan taken by Households from Banks (Yes/No)

Village	Yes	No	Total
Gurana	40 53.33* 19.42**	35 46.67* 37.23**	75 100* 25**
Vazidpur	42 56* 20.39**	33 44* 35.11**	75 100* 25**
Pura Mahadev	60 80* 29.13**	15 20* 15.96**	75 100* 25**
Mawi Kalan	64 85.33* 31.07**	11 14.67* 11.7**	75 100* 25**
Total	206 68.67* 100**	94 31.33* 100**	300 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage ** column percentage; Pearson chi2(3) = 27.94 Pr = 0.00

Analysing the data as per different farm-size categories credit facility is majorly availed by medium and large farmers with a percentage of 85 percent and 100 percent respectively taking loans for agricultural purposes. This clearly indicates that still credit penetration is low among marginal and small farmers.

5.3. Factors Determining Agricultural Production

After a comprehensive discussion on the various aspects of agriculture in the sampled villages across different land size group, a multiple regression model has been run between total production, villages and land size group. The following equation has been fitted:

$$Y_i = a + \beta_1 X_i + e_i$$

Total Production (log) = a + b1 * Mawi Kalan + b2 * Gurana + b3 * Pura Mahadev + b4 *Marginal + b5 * Small + b6 * Large + b7 *Income + b9 *Caste + b10 *Education

Wherein Yi = dependent variable viz. total production (log),

a= Intercept

X_i = Matrix of Explanatory variables

e_i = Error term

This model assess whether the hydrogeological, social and economic status of the village as well as land size has an impact i.e. positive or negative on total production or output. All the variables are statistically significant (as depicted through p-values) except dummy of large land size and education. The results of the model shown in Table 5.19 depict that total output would increase 0.35 units if the farm lies in Mawi Kalan (high groundwater stressed, socially economically backward village) while it would rise by 0.44 percent if it is in Gurana region and with 0.41 percent in case of Pura Mahadev. Such outcomes portray that Gurana village is more productive than Mawi Kalan and people here are in better position-socially, economically and hydrogeologically. Considering land size group, the regression results show that output in marginal farm category would reduce 1.32 percent and in small category it will dip down by 0.75 percent. The total production is estimated to increase by 0.57 percent if it's a large farm, suggesting large farms are productive within the sampled region. As far as association of household income with agricultural production is concerned, the results depict that households with less income are able to produce less. The influence of caste and religion on total production is also evident. Within the sampled region OBC category households are in better position socially and economically, therefore when a household belongs to this category agriculture output is expected to rise by 0.37 units. Further, the regression result shows that farmers belonging to Hindu religion category are able to produce more. The agricultural output is expected to rise by 0.62 units if farmer is a Hindu. Considering education, the regression estimates depict that if the farmer is literate then production would increase by 0.13 units.

Table 5.19: Result of Multiple Regression Model

VARIABLES	Total value of production (log)	t-values
Village Mawi Kalan Mawi Kalan=1, Others=0	0.35** (0.14)	2.50
Village Gurana Gurana=1, Others=0	0.44*** (0.14)	3.11
Village Pura Mahadev Vazidpur=1, Others=0	0.41*** (0.14)	2.87
Marginal Marginal=1 Others=0	-1.32*** (0.16)	-8.06

Small Small=1, Others=0	-0.75*** (0.17)	-4.36
Large Large=1, Others=0	0.57 (0.45)	1.26
Religion (Hindu=1 Others=0)	0.62*** (0.15)	3.91
Income (Bottom 60 percent=1; Others=0)	-0.32** (0.11)	-2.84
Caste (OBC=1; Others=0)	0.37*** (0.10)	3.51
Education (Literate=1; Others=0)	0.13 (0.11)	1.15
Constant	6.23*** (0.24)	25.32
Observations	300	
R-squared	0.41	

Source- Estimated from Field Survey Data

Note: Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$

5.4. Conclusion

The sampled villages differ with reference to socio-economic and hydrogeological conditions. Gurana and Vazidpur are the villages which are relatively better off while Pura Mahadev and Mawi Kalan lag behind in every. Taking these things into account an analysis of the agriculture profile of these villages has been done in this chapter. Primary data analysis shows that the production and productivity is much higher in Gurana and Vazidpur than Pura Mahadev and Mawi Kalan. The cost of cultivation is also lower in Gurana and Vazidpur in most of the land size categories. Considering the net returns, data reveals that across all land size categories Gurana farmers earn the maximum profit except in case of medium landholder wherein Mawi Kalan leads and is trailed by Gurana, Pura Mahadev and Vazidpur. Out of all the sampled villages it is Gurana wherein the water charges are the lowest and farmers shed fewer amounts in purchasing water as the water level is comparatively higher. The farmers in Gurana are able to reap maximum profits and due to this are in a position to invest in labour as well as agricultural machinery. The credit demand is also less in Gurana as farmers are able to generate enough income so as to fulfill their farm needs.

Focusing on the agriculture trends land size group wise, this chapter analysis reveals that it is the large farmer which benefits the most. The cost of cultivation with reference to marginal category in all the villages is highest while in case of large farmer the lowest, due to economies of size. The value of output per acre is highest in large farm sizes showing higher productivity levels. The net returns of large landholders are loftier than the small and marginal category farm owners. This suggests that inverse farm size and productivity relationship at macro level does not exist in these villages.

Chapter VI

Groundwater: The Scenario and Perception in the Surveyed Area

6.0. Introduction

Groundwater is becoming the most important natural resource to meet the water requirements in India as well as globally. Gandhi & Bhamoriya (2011, p.90) observed that the estimated total replenishable groundwater resource in India is 433.02 billion cubic metres (BCM) per year out of which about 93 per cent is available to agriculture sector and the utilizable groundwater resource is 381.16 BCM, or 88 per cent. This sector consumes 212 BCM, thereby the net groundwater development is about 58 per cent. Although, this percentage may not seem to be very scary but the situation is precarious in few states of the country wherein the groundwater development is extremely high. It is after the Green Revolution, groundwater use in agriculture sector surged and currently more than 60 percent of the agricultural land is irrigated through it. The most noteworthy change in the groundwater scenario in India is that the share of bore well irrigation rose up from 1 percent during 1960-61 to 60 percent during 2006-07 (Indian Agricultural Statistic, 2008, p.9). The total estimated number of groundwater schemes as of 2013-14 is 20.52 million. The absolute number of minor irrigation structure has grown over the period though at a slow pace. Dugwells (40 percent) are still more than the shallow (27 percent) and deep tubewells (12 percent). Deep tubewells have expanded fundamentally from 1.4 million (7percent) in 2006-07 to 2.6 million (12percent) in 2013-14. Surface water structures and surface lift schemes have registered a downfall of 3 percent respectively during 2006-07 to 2013-14. It has been observed that with receding water tables deep tubewells and shallow wells are taking up against the dugwells (Mukherji et.al, 2013, p.116). Uttar Pradesh leads in terms of ownership of minor irrigation schemes trailed by Maharashtra, Tamil Nadu and Madhya Pradesh etc (Verma et.al, 2017, p.2). There has been a gradual increase in the share of groundwater in irrigation due to its easy, flexible and reliable availability and access, lack of adequate canal infrastructure, absence of traditional water reservoirs, credit availability to farmers and sufficient marketing of submersible/ electric pumpsets has made groundwater the preferred option for meeting agriculture water demands.

This chapter has been prepared to address two main objectives. Firstly, to analyse the perception of farmers households about groundwater availability, accessibility, causes of water decline and apparent threat levels among farmers and their coping strategies across different socio-economic and physical setting. Secondly, to assess groundwater stress levels in different sampled villages and land size groups. In order to fulfill these objectives, through the use of an interview schedule few targeted questions were asked to all the 300 respondents i.e. 75 respondents from each sample village. A Groundwater Stress Index has been formed using the UNDP methodology and ranking of the villages has been done accordingly. Further, using descriptive statistics, an assessment of the perception, awareness and coping strategies as per the village and land size group categories has been presented. The main motive behind preparing this chapter is to showcase the groundwater scenario, to capture the inequalities and to decipher the ultimate beneficiary as per different villages and land size groups.

6.1. The Particulars of Groundwater Irrigation in Sampled Villages

According to CGWB (2015), the level of groundwater development is as high as 75 percent in Uttar Pradesh and the situation is extremely tense in Western part of the state and specifically in Baghpat district i.e. in the region where all our sample villages lie. Baghpat is the only district in the state which has none of its blocks in *safe* category. The overall groundwater development is one of the highest with 116.61 percent. Out of all the blocks in the district, the situation is precarious in Binauli and Pilana, where groundwater development is 154.08 and 131.50 percent respectively. Baraut having groundwater development of 85.57 percent is the only less affected block, thus, it falls in semi-critical category. Out of the four sample villages, Baraut and Vazidpur lies in Baraut block while Pura-Mahadev in Pilana and Mawi Kalan village in Binauli. The purpose of selecting these villages from different blocks is to comprehend the causes and effect of groundwater depletion in various hydrogeological settings.

(a) Groundwater Depth and Reasons for depletion

The water table is an underground boundary between the surface of the soil and the region where groundwater saturates among the silt and creaks in rock. The water table level can change in various territories and even within the region. Variances in the water table level are brought about by changes in precipitation and anthropogenic activities. The groundwater depth or water table can be estimated in existing wells to decide the impacts of season, atmosphere, or human effect on groundwater. The water table can really be mapped crosswise over locales utilizing estimations taken from these wells. Water availability at greater depths with every successive year is a sign of concern. In our study, due to limited resources we could not gauge the water table on our own but we tried to assess it indirectly by asking the respondents the depth of their respective motor pumps. In the table 6.1, we have presented the view of the usual depth of water in various villages as stated by the farmers. In Gurana, the average level at which water is available from is 70 ft below as 58.67 percent respondents mentioned it while 20.67 percent believed it to be 80 ft and just 14.67 percent had fixed their pumpset at 90 ft. In Vazidpur, 65.33 percent farmers told us that they are able to abstract water at almost 90 ft. while 21.33 percent revealed their pumpset was fixed at 80 ft and some percentage (13.33) were able to get water at 100 ft. In Pura Mahadev, 65.33 percent respondents stated 120 ft. as the usual groundwater depth whereas according to 22.67 percent it is 130 ft. In Mawi Kalan village, 54.67 percent were able to fetch water from the depth of 130 ft. while 33.33 percent mentioned the usual depth to be 120 ft. Overall, considering the inter-village groundwater depth levels, data reveals that groundwater level is relatively higher in Gurana and Vazidpur wherein the usual depth is 70 and 90 ft respectively while it is lower in Pura Mahadev and Mawi Kalan where the groundwater is available at a depth of 120ft and 130 ft. respectively. These responses clearly support the secondary data view that groundwater stress is particularly high in blocks of Pilana and Binauli where Pura Mahadev and Mawi Kalan lie. Water is available at low levels ranging from 20-45 m bgl across all villages which is a troublesome matter.

Table 6.1: Village wise Respondents View about the Usual Depth of Groundwater

Village	70 ft[1].	80 ft.	90 ft.	100 ft.	110 ft.	120 ft.	130 ft.	Total
Gurana	44 58.67* 100**	20 26.67* 55.56**	11 14.67* 18.33**	0 0* 0**	0 0* 0**	0 0* 0**	0 0* 0**	75 100* 25**
Vazidpur	0 0* 0**	16 21.33* 44.44**	49 65.33* 81.67**	10 13.33* 76.92**	0 0* 0**	0 0* 0**	0 0* 0**	75 100* 25**
Pura Mahadev	0 0* 0**	0 0* 0**	0 0* 0**	2 2.67* 15.38**	7 9.33* 46.67**	49 65.33* 66.22**	17 22.67* 29.31**	75 100* 25**
Mawi Kalan	0 0* 0**	0 0* 0**	0 0* 0**	1 1.33* 7.69**	8 10.67* 53.33**	25 33.33* 33.78**	41 54.67* 70.69**	75 100* 25**
Total	44 14.67* 100**	36 12* 100**	60 20* 100**	13 4.33* 100**	15 5* 100**	74 24.67* 100**	58 19.33* 100**	300 100* 100**

Source- Estimated from Field Survey Data;
Note:*row percentage **column percentage; Pearson chi2 = 478.89   Pr = 0.00

[1] Ft.= Feet (below the ground level)

Taking into consideration the usual pattern of groundwater depth, the respondents revealed that such low levels have been a recent phenomenon. According to them, the water was available at 30-50 ft. almost ten years back but the situation is turning grave year by year. A question was then posed to them regarding the major cause of water table decline. The view of the farmers has been presented in Table 6.2. The frequency distribution shows that in Gurana, 54.67 percent stated inadequate canal infrastructure to be the main reason while 24percent cited access to technology for fetching deep water as the primary reason. The other respondents stated inexpensive electricity and easy and flexible use through submersible/ pumpsets to be one of the principal reasons for water table decline. In Vazidpur, 65.33 percent expressed inadequate canal infrastructure to be the supreme reason while 22.67 percent considered access to technology for water table's downward movement. In Pura Mahadev 69.33 percent considered lack of adequate canal irrigation system to be the foremost reason while 22.67percent cited access to technology as the main cause for water table decline in the region. Likewise in Mawi Kalan 52 percent respondents mentioned inadequate surface water irrigation as the major cause for rising groundwater stress while 16 percent considered access to technology as the main reason and another 12 percent stated easy and flexibility in use as the primary reason. Overall, in all the sample villages, the supreme reason for water decline is inadequate canal infrastructure followed by access to groundwater abstraction technology and easy and flexible property of groundwater to be the key drivers of increased groundwater depth.

Table 6.2: Village wise Respondents View about the Primary Reason behind Water Table Decline

Village	Could Not State	Access to Technology	Inexpensive Electricity	Inadq[2].Canal Infra	Easy &Flexibility	Total
Gurana	0 0* 0**	18 24* 28.13**	9 12* 45**	41 54.67* 22.65**	7 9.33* 30.43**	75 100* 25**
Vazidpur	0 0* 0**	17 22.67* 26.56**	5 6.67* 25**	49 65.33* 27.07**	4 5.33* 17.39**	75 100* 25**
Pura-Mahadev	0 0* 0**	17 22.67* 26.56**	3 4* 15**	52 69.33* 28.73**	3 4* 13.04**	75 100* 25**
Mawi Kalan	12 16* 100**	12 16* 18.75**	3 4* 15**	39 52* 21.55**	9 12* 39.13**	75 100* 25**
Total	12 4* 100**	64 21.33* 100**	20 6.67* 100**	181 60.33* 100**	23 7.67* 100**	300 100* 100**

Source: Estimated from Field Survey Data
Note: *row percentage **column percentage Pearson chi2 = 48.71   Pr = 0.00

The results of Table 6.1 and 6.2 are in consistency with the macro level picture as discussed by various scholars. According to Dhawan (2017, p.8) the Government of India has initiated many programmes to improvise and enhance canal irrigation system with an approx. investment of US$ 4000 million during 1991-2007 but still the canal irrigated area has reduced over the years. Old infrastructure, unreliable water availability and supply have made farmers to shift from canal irrigation to groundwater based irrigation. A similar view regarding the substandard canal irrigation system is shared by Shah (2011, p.4) who mentions in his study that the governments have made huge expenditure on canal construction but the operations and maintenance level is "pathetic".

From the above tables, we see that respondents in different villages consider easy and flexibility in groundwater abstraction after installation of submersible/electric pumpset. Siebert et.al. (2010, p.1863) mentioned that "groundwater offers reliability and flexibility in access to water that irrigation canals can hardly match". According to Hoogester and Wester (2017, p.107) with increase in tubewell technologies groundwater is readily available on -time and on -demand of the farmer thereby making it as the most preferred and reliable source of water.

[2] Inadequate canal infrastructure

We are concerned about the depth of the groundwater because it shows the condition of the aquifer. Farmers may not be aware about the groundwater science but we as researchers have the responsibility to analyse the present situation as well as the consequences of over abstraction. In all the sampled villages, we see the water is extracted from greater depths i.e. ranging from 70 ft. to 130 ft. Installation of more pumps or deepening of wells may cause a further decline in water levels which will negatively affect the agricultural cost and productivity in farming.

(b) Ownership of Pumpsets

A centrifugal pump is incapable of lifting groundwater when the water table has declined beneath a specific level. By and large, in the north-western regions of India, the utmost limit upto which it can extract water is 40 feet. Faced with fall in the groundwater level, a farmer either digs deeper bore or shift to submersible pump. A large proportion of the farmers who had resources abandoned the use of centrifugal pumps and installed submersible pumpset, as their pumping length is boundless. However, it is important to understand over here that use of submersible pumpset is the need of the hour but unsustainable use is inappropriate. At the point when water is siphoned from a well, it causes water levels in the well and nearby aquifer to decrease, alluded to as "drawdown." This drawdown thusly makes a pressure driven slope that draws water from the aquifer towards the well to supplant water the pump expels from the well. This drawdown and water expulsion causes an imbalance in the natural equilibrium of aquifer (CAST, 2011). Therefore, implying that deepening of wells and installation of more pumps aggravates water table decline. In this context, in order to estimate the penetration of submersible pumpsets in our study area farmers were asked whether they own a submersible or not. Table 6.3 has been presented to show the percentage of ownership of submersible pumpsets in each village and in each landholding size category. In Gurana, out of the total 55 farmers who owned a certain type of agricultural machinery, 83.64 percent owned a pumpset while 16.36 percent did not. In Vazidpur, out of the total 57 farmers 48 owned submersible/ electric pumpsets and 15.79 percent did not possess pumpsets. In Pura Mahadev 88.71 percent owned a submersible/electric pumpset and in Mawi Kalan the percent was the highest with 94.83percent possessing pumpsets. Overall, we see that majority of the farmers in all villages depend upon pumpsets for irrigation. Inter- village frequency distribution shows that ownership of pumpsets is relatively lower in Gurana and Vazidpur than Pura Mahadev and Mawi Kalan. This scenario could be seen from two sides; 1) higher percentage of pumpsets owners has promoted groundwater scarcity in Pura

Mahadev and Mawi Kalan, 2) As the groundwater level is lower in these villages and so the viable option that the farmers have is to install a pumpset on farm. The water charges due to high groundwater stress is also high and small/marginal farmers instead of paying huge amount to large farmers consider installation of pumpsets on their own farms.

Table 6.3: Village wise Ownership of Submersible Pumpset

Village	No	Yes	Total
Gurana	9 16.36* 32.14**	46 83.64* 22.55**	55 100* 23.71**
Vazidpur	9 15.79* 32.14**	48 84.21* 23.53**	57 100* 24.57**
Pura-Mahadev	7 11.29* 25**	55 88.71* 26.96**	62 100* 26.72**
Mawi Kalan	3 5.17* 10.71**	55 94.83* 26.96**	58 100* 25**
Total	28 12.07* 100**	204 87.93* 100**	232 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage **column percentage; Pearson chi2 = 4.33 Pr = 0.22

In this context, it is also necessary to see the inter-land size differentials i.e. whether medium or large farmer's ownership of pumpsets is higher than marginal/small farmers. Considering land wise pumpset ownership pattern (Appendices, table 6.3A), 86.51percent owned submersible in the marginal land size group and 13.49 percent did not. In small farm size category 87.69 percent had ownership of pumpsets while 12.31 percent could not possess it. In medium category 91.89 percent owned a pumpset and in large category all the farmers possessed a submersible. Table 6.5 suggests that in large and medium category a higher percentage of famers have submersible and only a few lack it while in marginal and small category, 25.08 percent in total could not own it. This throws light on the fact that marginal and small farmers lag behind in accessing groundwater through pumpsets. According to report in Livemint (2019, pp.1-2) by Satyanan Bera, a large number of marginal farmers are deprived of electric pumpsets and are dependent on large farmers to purchase water at a high rate. According to Manjunatha (2014, pp. 46-47) resource poor farmers (usually small farmers) i.e. who could not afford to install pumpsets on farm purchase water from large famers. Such a system has paved way for groundwater markets in different states. It has been reported that out of 82 million farmers, 25.6 per cent (21 millions) owned water extraction mechanisms. Additionally, 24 million farmers have reported renting of irrigation services (Mukherji, 2007, p.6419).

Exploring the energy scenario of pumpsets table 6.4 has been presented which reveal the frequency distribution of pumpsets with different horsepower within the sampled villages and landholding categories. In Gurana majority of the respondents had pumpsets with horsepower of 10 and above while only a minor percent owned a pumpset with lower power. In Vazidpur 43 farmers i.e. almost 89percent owned a submersible with 12.5 horsepower. Likewise in Mawi Kalan and Pura Mahadev almost all the farmers who owned a pumpsets could not depend upon a submersible with lower horsepower i.e. 3, 5 or 7 horsepower therefore they largely relied upon the pumpsets within the 10 to 12.5 horsepower. Out of the total 204 farmers who had ownership of submersible 186 had pumpsets with more than 10 horsepower.

Table 6.4: Village wise Distribution of Submersible Pumpsets according to Horsepower (HP)

Village	Upto 5 HP	6-10 HP	Above 10	Total
Gurana	0 0* 0**	7 15.22* 70**	38 82.61* 20.65**	46 100* 22.55**
Vazidpur	2 4.17* 25**	3 6.25* 30**	42 87.5* 22.83**	48 100* 23.53**
Pura-Mahadev	6 10.91* 75**	0 0* 0**	49 89.09* 26.63**	55 100* 26.96**
Mawi Kalan	0 0* 0**	0 0* 0**	55 100* 29.89**	55 100* 26.96**
Total	8 3.92* 100**	10 4.9* 100**	186 91.18* 100**	204 100* 100**

Source- Estimated from Field Survey Data
Note:*row percentage **column percentage; Pearson chi = 36.14 Pr = 0.00

In marginal category (Appendices, table 6.4A), 89.91 percent had pumpsets with horsepower of 10 and above while only a minor i.e. 4.59 percent owned a pumpset with less than 5 horsepower.

In small category 51 farmers i.e. almost 87percent own a submersible with 12 horsepower. Likewise in large and medium almost all the farmers who owned a pumpsets could not depend upon a submersible with lower horsepower i.e. 3, 5 or 7 horsepower therefore they largely depend upon the pumpsets within the 10 to 12.5 horsepower. Out of the total 204 farmers who had ownership of submersible 186 had pumpsets with more than 10 horsepower. Village and land size wise pumps horsepower pattern reveals that majority of the agriculturists use pumpsets with more than 10 hp. According to Dharmadhikari et.al. (2018, p.7) falling groundwater levels in several areas have lead to usage of high horsepower pumpsets to fetch same amount of water. As per USGS, when the depth to water increases, greater amount of energy is required to lift water above the surface. For this purpose, pumpsets with high power are installed which enables water abstraction but increases the energy cost of the farmer. The farmers in our study stated that they were able to abstract water ten years back even from a centrifugal pump but now they have installed a submersible and its pumping length has to be increased almost every year or two. This depicts a worrisome situation.

(c) Awareness among Farmers about Energy Efficiency

The efficiency of an appliance is characterized by its ability of converting electrical energy into some other form of energy. Each pumpset is intended to deal with certain load at which it has the most ideal productivity (called Best Efficiency Point). Most effective pumps have efficiencies within the range of 50-70 percent. (Jain, 2016, p.1). About 500 thousand pumps are included every year, a large portion of these are not energy efficient (Sant and Dixit, 1996, p.1). The water pumpsets being commonly used in India are operating at 30 percent lower than their capacity level. Their optimal efficiency is not achieved because they larger than required (installed in order to siphon more water from progressively declining water tables and furthermore to withstand high voltage fluctuations), lack maintenance and use high friction piping (Energy Management Centre, 2018, pp.16-17). Further, as the agriculture sector is profoundly subsidised the farmers have minimal motivating force for effective utilization of power. In our study area, we found farmers saying that their energy expenditure has also increased during last few years. It has happened so due to the declining groundwater depths and another key factor behind it might be inefficient pumpsets. An inefficient pump requires more energy to abstract same amount of water to a specific height. Thus, to assess their knowledge and use of energy efficient pumps, a question was about the same. The results show (in table 6.5) that in Gurana 81.33 percent had no awareness about the availability of energy efficient pumpsets while 18.67 percent had information about it. In Vazidpur, 32percent knew about water and energy efficient pumpsets while 68 percent were unaware about it. In Pura Mahadev, 90.67 percent had no idea about it while 9.33 percent said that they have some information regarding such pumps. In Mawi Kalan, 85.33 percent were not aware about the availability of water and energy saving pumps in the markets while 14.67 percent had knowledge about it. Overall 18.67 percent in the sampled villages were aware about the availability of water and energy saving pumps while 81.33 percent had no idea.

Table 6.5: Village wise Awareness about Energy efficient pumps

Village	Yes	No	Total
Gurana	14 18.67* 25**	61 81.33* 25**	75 100* 25**
Vazidpur	24 32* 42.86**	51 68* 20.9**	75 100* 25**
Pura-Mahadev	7 9.33* 12.5**	68 90.67* 27.87**	75 100* 25**
Mawi Kalan	11 14.67* 19.64**	64 85.33* 26.23**	75 100* 25**
Total	56 18.67* 100**	244 81.33* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note :*row percentage **column percentage; Pearson chi2(3) = 13.8759 Pr = 0.003

The low level of awareness among farmers about energy efficiency is showcased in the type of pumpsets being currently used by them. Farmers across all the villages had no preference for purchasing an energy efficient pumpset of particular brand. Peer influence is the main guiding factor behind purchase of agricultural equipments viz. water pumpset. According to Verma et.al. (undated) the pump sets which are nowadays being operated in Indian agriculture are very low efficient pumps sets (20-35 percent). Their use and demand is high because they are affordable by small/marginal farmers. Various studies undertaken by World Bank (2001, p.2), WENEXA (2007, pp.3-4) have also witnessed the poor level of efficiency of these agriculture pump sets.

(d) Farmer's Perception about Water Stress

We now focus on the behavioral aspect of farmers regarding groundwater use and attitude towards its management. Access to increasingly scarce natural resources lies at the heart of many local and (inter)national conflicts as many resources have multiple uses (Hauge and Ellingsen 1998, p.37). Since the pioneering work of Gordon (1954), many bio-economic models for the description of the commercial exploitation of common property renewable resources, such as fisheries, have stressed the problem known as 'the tragedy of the commons' (Hardin, 1968; Clark, 1990, p.10). Before, studying the strategy followed by the farmers in our case, we need to understand their perception of threat if the neighbouring farmer drills deeper or drills more wells. Analysing it village wise (table 6.6), frequency distribution shows that overall majority of the respondents (92.33 percent) considered construction of borewell or installation of a pumpset by a neighbouring farmer as a threat to them while 7.67 percent answered that it would not affect them. In Gurana, 92 percent agreed that construction of a borewell would negatively impact them and just 8 percent denied it. In Vazidpur, wherein the water situation is not as grave as in Pura Mahadev and Mawi Kalan 85.33 percent accepted that drilling deeper or installation of a pumpset will affect their water availability while 14.67 percent did not agree to it. In Pura Mahadev 94.67 percent regarded boring as a threat while 5.33 percent did not considered it to be so. In Mawi Kalan 97.33 percent farmers believed that construction of a borewell or installation of a pumpset by a neighbouring farmer will impact their water availability negatively while 2.67 percent stated otherwise. Therefore, the broader picture depicts that the threat perception is extremely high in Mawi Kalan and Pura Mahadev and relatively less in Vazidpur. The prime reason for this low level of perceived stress in Vazidpur and Gurana is the better hydrological conditions i.e. groundwater scenario.

Table 6.6: Village wise Perception of threat due to installation of pump by the neighbouring farmer

Village	Yes	No	Total
Gurana	69 92* 24.91**	6 8* 26.09**	75 100* 25**
Vazidpur	64 85.33* 23.1**	11 14.67* 47.83**	75 100* 25**

Pura-Mahadev	71 94.67* 25.63**	4 5.33* 17.39**	75 100* 25**
Mawi Kalan	73 97.33* 26.35**	2 2.67* 8.7**	75 100* 25**
Total	277 92.33* 100**	23 7.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note:*row percentage **column percentage; Pearson chi2(3) = 8.42 Pr = 0.03

(e) Strategies of farmers regarding competition in water use

Farmer's behaviour is driven by the gravity of stress which is slightly less in these villages. Behavior is a function of the person, the environment, and the interaction between the two. Therefore if the person's environment is not much acceptable then the person starts behaving in an undesirable manner. Paying attention on the behavioral aspect of farmers regarding their response or their dominant strategy if neighbouring farmers drill deeper or drill more wells, table 6.7 has been made. Overall 48.33percent of the respondents considered drilling deeper to be the best strategy while 17.6percent answered that they would request the farmer to reduce his abstraction and 11.67 percent referred to as installation of powerful pumpset as the major strategy. In Gurana 46.67 percent revealed that drilling deeper is the best tool in such a scenario while 16 percent each considered drilling more wells and asking to reduce abstraction as dominant strategies. In Vazidpur, 56 percent said that drilling deeper is the apt solution in such a situation while 10.67percent each considered drilling more wells and installation of powerful pumpsets as main strategies while 13.33 percent responded that they will do nothing. In Pura Mahadev, according to 61.33percentdrilling deeper is the primary way in such a scenario while 17.33percentsaid asking to reduce abstraction is their choice. In Mawi Kalan, 30.67 percent responded that they would ask the neighbouring farmer to reduce this abstraction while 29.33 considered drilling deeper to be the primary strategy. In Mawi Kalan and Pura Mahadev, there is higher level of aversive water stress, therefore the respondents in these villages opted for fierce strategy. Such a picture reveals the competitive behaviour of farmers which would eventually lead to higher levels of groundwater depletion. This problem can be basically identified with a prisoner's dilemma because the presence of firms playing their dominant strategy which maximizes their own profit (disregarding competitors' profits) leads to severe depletion of the resource, and consequently to low profits for all (Bischi et.al, 2004, pp.1-2).

Table 6.7: Village wise Primary Strategy for Securing Water Flow

Village	Cannot Say	Drill deep	Drill More	Powerful Pump	Reduce Use	Sustainable Use	Do Nothing	Others	Total
Gurana	2 2.67* 25**	35 46.67* 24.14**	12 16* 44.44**	9 12* 25.71**	12 16* 22.64**	1 1.33* 100**	4 5.33* 14.29**	0 0* 0**	75 100* 25**
Vazidpur	2 2.67* 25**	42 56* 28.97**	8 10.67* 29.63**	8 10.67* 22.86**	5 6.67* 9.43**	0 0* 0**	10 13.33* 35.71**	0 0* 0**	75 100* 25**
Mawi Kalan	0 0* 0**	22 29.33* 15.17**	4 5.33* 14.81**	14 18.67* 40**	23 30.67* 43.4**	0 0* 0**	10 13.33* 35.71**	2 2.67* 66.67**	75 100* 25**
Pura-Mahadev	4 5.33* 50**	46 61.33* 31.72**	3 4* 11.11**	4 5.33* 11.43**	13 17.33* 24.53**	0 0* 0**	4 5.33* 14.29**	1 1.33* 33.33**	75 100* 25**
Total	8 2.67* 100**	145 48.33* 100**	27 9* 100**	35 11.67* 100**	53 17.67* 100**	1 0.33* 100**	28 9.33* 100**	3 1* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note :*row percentage **column percentage; Pearson chi2= 50.74 Pr = 0.00

The above table which present the behavioural tendencies of individuals show that they are confronted with a dilemma i.e. to pursue self interest or cooperate. The results reveal that majority of the individual chose self interest which would eventually lead to higher level of exposure to environmental risks. According to Yan & Jiang (2018) "the existence of group influence aggravates people's herd psychology. People are more willing to believe and follow the behavior of the majority". This is what we observe in case of farmers wherein they simply follow the methods adopted by their peers and in doing so overlook the present and future circumstances. Considering pumpset ownership in this context, we saw that a large number of farmers had the same type and same brand and same horsepower pumpsets. Peer or group influence is so strong that they follow it blindly and anyone who drifts away from the group is considered to be at fault. Groundwater stress is persistent in all the villages but is relatively higher in Pura Mahadev and Mawi Kalan still farmers are not ready to practice sustainable use at their own farm rather are willing to ask the neighbouring farmer to reduce his/ her own water use.

6.2. Groundwater and Land Inequity

(a) Groundwater Markets

Groundwater scarcity has paved way for water markets. According to Kolvalli and Chicoine (2007, p.38) markets for groundwater have emerged where well owners have surplus water and there is high demand for irrigation water. Well owners are usually large/medium farmers who can afford to install huge power pumpsets. Selling water has become an added source of income for them, has increased the return on groundwater investments. Such water markets have on one hand has improvised the groundwater accessibility to small/marginal farmers but monopoly pricing is unjust. It is land inequality which is highly skewed towards large farmers and they have huge capital investment and relatively better consolidation of land holdings which makes groundwater abstraction viable (Dhawan, 1982, p.4; Shah, 1993, p.7). Working in this context, this block of the chapter attempts to decipher the linkage between groundwater accessibility and land inequities. Across all sampled villages, groundwater markets prevail and this was confirmed by 95.67 percent respondents (Appendices, table 6.8 A). Taking into account the land wise perception about groundwater accessibility through water markets table 6.8 has been prepared. Out of the total 300 respondents 95.67 percent responded that there exists informal arrangements for small scale farmers to access groundwater while 4.33 percent believed that no such system prevails. In marginal land size group 97.18 percent respondents agreed about the existence of informal arrangements regarding water accessibility while 2.82 percent did not agree to it. In small land size category 93.67 percent farmers believed that informal arrangements for ground water abstraction is present while 6.33 percent stated otherwise. In medium category 92.50 percent farmers mentioned that groundwater was accessed by small scale farmers through informal system. In large category, all the farmers agreed to it. This data suggests that groundwater markets prevalence is high and a large proportion of farmers are dependent on it for meeting their irrigation needs.

Table 6.8: Land Size Group Perception about existence of Informal Arrangement for Groundwater Accessibility

Land Size	Yes	No	Total
Marginal	172 97.18* 59.93**	5 2.82* 38.46**	177 100* 59**
Small	74 93.67* 25.78**	5 6.33* 38.46**	79 100* 26.33**
Medium	37 92.5* 12.89**	3 7.5* 23.08**	40 100* 13.33**
Large	4 100* 1.39**	0 0* 0**	4 100* 1.33**
Total	287 95.67* 100**	13 4.33* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note :*row percentage **column percentage; Pearson chi2(3) = 2.87 Pr = 0.41

(b) Inequality in accessibility to water

In order to understand people's understanding about the equity in groundwater availability a question on it was posed. Village wise we asked about whether they think access to groundwater is equal between small scale and large scale farmers. Out of the total 300 respondents (Appendices, table 6.9A), 8.67 percent responded that access to groundwater is equal between the two categories while 91.33 percent believed that no such equality prevails. In Gurana, 16 percent said yes to this phenomenon while 84 percent answered negatively. In Vazidpur, 18.67 percent farmers agreed about the existence of equality while 81.33 percent did not. In Pura Mahadev and Mawi Kalan all the farmers believed that such equality persist. Assessing the situation landholding size wise (table 6.9), out of the total 300 respondents 8.67 percent responded that access to groundwater is equal between the two categories while 91.33 percent believed that no such equality prevails. In marginal category 6.78 percent said yes to this phenomenon while 93.22 percent answered negatively. In small category 13.92 percent farmers agreed about the existence of equality while 86.08 percent did not. In medium and large category 5 percent and 25 percent farmers respectively believed that such equality persist. In our study area, the situation of marginal/ small farmers is no better than the macro level scenario. They are the highly vulnerable group having difficulties in accessing resources viz. land, water, equipments and credit etc. High level of Indebtness clubbed with large family size, illiteracy and social exclusion (in terms of poverty, caste, religion) adds to their misery.

Table 6.9: Land Size group wise Respondent's view on Equity between Small scale and large scale farmers

Land Size	Yes	No	Total
Marginal	12 6.78* 46.15**	165 93.22* 60.22**	177 100* 59**
Small	11 13.92* 42.31**	68 86.08* 24.82**	79 100* 26.33**
Medium	2 5* 7.69**	38 95* 13.87**	40 100* 13.33**
Large	1 25* 3.85**	3 75* 1.09**	4 100* 1.33**
Total	26 8.67* 100**	274 91.33* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note :*row percentage **column percentage; Pearson chi2(3) = 5.58 Pr = 0.13

(c) Land Integration and water accessibility

In view of land disparities and groundwater accessibility land integration can provide a solution. The farmers were asked if land integration can improve farmers' access to water and enhance irrigation efficiency (Appendices, table 6.10A). In Gurana, 97.33 percent respondents that land integration would improve farmer's access to water and thereby improve irrigation efficiency. Almost similar situation prevail in all the villages i.e. majority of the respondents believed that land integration is an effective solution to increase accessibility of water among all land size categories. Out of the total 93 percent agreed while 7percent answered in a negative way.

Checking the farmer's view in this regard with reference to land size group table 6.10 has been presented. In marginal category, 93.79 percent respondent said that land integration would improve farmer's access to water and thereby improve irrigation efficiency. Almost similar situation exist in all the villages i.e. majority of the respondents believed that land integration is an effective solution to increase accessibility of water among all land size categories. Out of the total 93 percent agreed while 7 percent answered in a negative way.

Table 6.10: Land Size wise Respondent's view on Land Integration to improve water and irrigation efficiency

Land Size	Yes	No	Total
Marginal	166 93.79* 59.5**	11 6.21* 52.38**	177 100* 59**
Small	71 89.87* 25.45**	8 10.13* 38.1**	79 100* 26.33**
Medium	38 95* 13.62**	2 5* 9.52**	40 100* 13.33**
Large	4 100* 1.43**	0 0* 0**	4 100* 1.33**
Total	279 93* 100**	21 7* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note:*row percentage **column percentage; Pearson chi2(3) = 1.90 Pr = 0.59

From the above tables it is clear land ownership status affects groundwater accessibility. Therefore, to have an opinion about the same a simple question was asked to the farmers that how much land ownership status affects social equity in terms of accessing groundwater and irrigation distribution systems. Village wise views (table 6.11A) in this regard show that in all the sampled villages, 47.33 percent farmers consider it affects to a great extent while 43.67 percent say it influences moderately and only 9 percent consider it to be low. Analysing it landholding wise (refer table 6.11), it is observed that in marginal category 47.46 percent farmers believed that land ownership status highly effects social inequity in terms of accessing ground water and irrigation distribution system while 44.07 percent said that it moderately affects and 8.47 percent responded that its effect is low. In small category 39.24 percent farmers believed that accessing ground water and irrigation distribution system is influenced by land ownership status while 51.90 percent said that it moderately affects and 8.86 percent responded that its effect is low. In medium and large land size group 65 percent and 25 percent respectively believed that farmers land ownership status has an significant effect upon social inequity in terms of accessing ground water and irrigation distribution system while 25 percent and 50 percent each said that it moderately affects and 10percent and 25 percent each responded that its effect is low. The data depicts that marginal and small farmers strongly believes that land ownership status affects groundwater accessibility the most as they are the ones who are suffering facing this problem.

Table 6.11: Land Size Group wise Respondent's view on Effect of Land ownership status on Social Equity in terms of Groundwater Accessibility

Land Size	High	Moderate	Low	Total
Marginal	84 47.46* 59.15**	78 44.07* 59.54**	15 8.47* 55.56**	177 100* 59**
Small	31 39.24* 21.83**	41 51.9* 31.3**	7 8.86* 25.93**	79 100* 26.33**
Medium	26 65* 18.31**	10 25* 7.63**	4 10* 14.81**	40 100* 13.33**
Large	1 25* 0.7**	2 50* 1.53**	1 25* 3.7**	4 100* 1.33**
Total	142 47.33* 100**	131 43.67* 100**	27 9* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note:*row percentage **column percentage; Pearson chi2(6) = 9.85 Pr = 0.13

(d) Obstacles behind water security

Further considering the main obstacle that exists against their water security, village wise view show that in (Appendices, table 6.12A) Gurana, 57.33 percent farmers agreed that land rights are the major obstacle while 20percent believed economic backwardness as the main cause. In Vazidpur, 65.33 percent said that land rights is a major reason behind inadequate water security while 14.67 percent considered lack of government support as the major hindrance. The percentage of farmers believing that economic backwardness is the primary obstacle is 13.33 percent. In Pura Mahadev and Mawi Kalan majority of the farmers consider land rights to be the reason behind insufficient water security. In Pura Mahadev 6.67 percent each consider economic backwardness and government support as major obstacles. However in Mawi Kalan 14.67 percent believed caste of the farmer to be a significant factor.

As per land size group (refer table 6.12), data shows that in marginal farm size group 56.5 percent believed that land rights is the major reason behind their water insecurity while 15.82 percent consider caste to be the primary factor. In small farm size group 73.42 percent revealed that land rights act as a hindrance towards water security while 13.92 percent considered economic status to be the reason. In medium farm size group 82.5 percent responded that land ownership status is the obstacle that exists against water rights and 12.5 percent believed lack of government support as a major factor. In large category 75 percent termed land rights to be the most important obstacle while 25 percent thought it is the lack of government support.

Table 6.12: Land Size group wise Respondent's view on Main Obstacle behind Water Insecurity

Land Size	Land right	Caste	Gender	Govt. Support	Economic	Others	Total
Marginal	100 56.5* 51.55**	28 15.82* 93.33**	2 1.13* 66.67**	21 11.86* 63.64**	26 14.69* 68.42**	0 0* 0**	177 100* 59**
Small	58 73.42* 29.9**	2 2.53* 6.67**	0 0* 0**	6 7.59* 18.18**	11 13.92* 28.95**	2 2.53* 100**	79 100* 26.33**
Medium	33 82.5* 17.01**	0 0* 0**	1 2.5* 33.33**	5 12.5* 15.15**	1 2.5* 2.63**	0 0* 0**	40 100* 13.33**
Large	3 75* 1.55**	0 0* 0**	0 0* 0**	1 25* 3.03**	0 0* 0**	0 0* 0**	4 100* 1.33**
Total	194 64.67* 100**	30 10* 100**	3 1* 100**	33 11* 100**	38 12.67* 100**	2 0.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data

Note:*row percentage **column percentage; Pearson chi2(15) = 33.13 Pr = 0.00

Therefore, from the above tables it is clearly evident land ownership and groundwater accessibility are inter-related. Groundwater is part and parcel of the land and there is no separate title of ownership over groundwater. The large farmers are able to invest in installation of powerful pumpsets and thereby fetch more water consequently reducing the share of others.

Landless, marginal and small farmers who are resource poor, lack access to sufficient water for irrigation purposes and have to depend upon water landlords. Such de-jure water rights have impeded unsustainable use and created water markets. Small and marginal farmers are at the receiving end and will suffer from increasing irrigation costs with rising water stress.

6.3. Groundwater Contamination and Illness

Groundwater contamination is nearly always the result of human activity. In areas where population density is high and human use of the land is intensive, ground water is especially vulnerable. Ground water can become contaminated from natural sources or numerous types of human activities. Residential, municipal, commercial, industrial, and agricultural activities can all affect ground water quality (EPA, 2019, pp.2-3). According to CPCB (2007, p.4), the permeating water gets a lot of disintegrated constituents and achieves the aquifer framework and defiles the groundwater. A dominant part of groundwater quality issues are brought about by defilement, over-abuse, or blend of the two. Most groundwater quality issues are hard to distinguish and difficult to determine. The arrangements are generally extravagant, tedious and not constantly compelling. A disturbing picture is starting to develop in numerous regions of India. Due to water scarcity and rising pollution levels outbreaks of waterborne disease continue to occur in both developed and developing countries. Groundwater pollution involves extraordinary concern since it's the essential wellspring of drinking water. All through the world, there is proof of debased groundwater prompting flare-ups of ailment and adding to foundation endemic illness (Howard et.al. 2006, p.3). Diarrhea disease, which are largely derived from poor water and sanitation, accounted for 1.8 million deaths in 2002 and contributed around 62 million Disability Adjusted Life Years per annum (WHO, 2004, pp.3-4).

In our sample population in different villages, 164 households out of the total 300 responded that they have a patient suffering from water related disease (diarrhea, typhoid, jaundice, cholera, viral hepatitis, gastrointestinal problems and others). Table 6.13 presents the picture of water related illness. In Gurana, 44 percent households had patient with water related illness while 56 percent did not report any case. In Vazidpur, 52 percent households did not suffer from water borne diseases but 48 percent had such patients. In Pura Mahadev, the percentage of households with a patient of water related disease is 68 percent and likewise in Mawi Kalan majority of the households face illness caused by contaminated water.

Table 6.13: Village wise Frequency distribution of Households Suffering from Water related Illness (Yes/No)

Village	No	Yes	Total
Gurana	42 56* 30.88**	33 44* 20.12**	75 100* 25**
Vazidpur	39 52* 28.68**	36 48* 21.95**	75 100* 25**
Pura-Mahadev	24 32* 17.65**	51 68* 31.1**	75 100* 25**
Mawi Kalan	31 41.33* 22.79**	44 58.67* 26.83**	75 100* 25**
Total	136 45.33* 100**	164 54.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note :*row percentage **column percentage; Pearson chi2 = 14.09 Pr = 0.00

Checking out the total number of cases of different water related diseases in each sampled village table 6.14 is presented below. Overall, there have been 203 cases of such diseases with highest number of patients suffering from diarrhea followed by typhoid, liver infections and gastro troubles. In Gurana, 14 individuals experienced diarrhea in the family units we reviewed while 12 had typhoid and 4 experienced liver diseases. The all out number of patients with occurrence of water related illness is 32 in Gurana. In Vazidpur, 15 instances of typhoid and 11 instances of diarrhea are accounted for. In Pura Mahadev, 31 cases of diarrhoea, 18 typhoid, 10 instances of (hepato) liver contamination are conveyed. In Mawi Kalan, the rate of diarrhea and typhoid is high with 29 and 22 cases individually. The information demonstrates that the frequency of water related ailment is high in Pura Mahadev and Mawi Kalan. Considering the incidence of disease burden in each village as a proportion of total households as per Census, 2011 it is estimated that in Vazidpur it is the lowest with 2.9 percent suffering from water related diseases followed by Gurana (4.2 percent), Mawi Kalan (8.30 percent) and Pura Mahadev (13.74 percent) out of the total number of households in all the sampled villages.

Table 6.14: Village wise Number of Cases of Various Water Related Diseases

Village	Cholera	Malaria	Typhoid	Jaundice	Diarrhoea	Hepato	Gastro	Nephro	Total
Gurana	0	0	12	1	14	4	1	0	32
Vazidpur	0	2	15	1	11	4	4	0	37
Pura-Mahadev	4	0	18	0	31	10	5	1	69
Mawi Kalan	0	0	22	0	29	9	3	2	65
Total	4	2	67	2	85	27	13	3	203

Source: Estimated from Field Survey Data, Note: Gastro = Gastrointestinal Problems, Nephro= Nephrological Diseases (Kidney Problems), Hepato= Hepatological Diseases (Liver Problems)

6.4. Determinants of Health Hazards in Groundwater Stressed Villages

In order to ascertain the determinants of illness the following logistic regression model is fitted to capture the probability of suffering from the above mentioned diseases farmers depending upon socio-economic factors.

$$Y_i = ln\frac{P_i}{1-P_i} = \alpha_i + \beta_i X_i + e_i \qquad (1)$$

Y_i represents whether any member in the households suffers from any kind of water related disease as dependent variable; X_i is the matrix of explanatory variables comprising all socio-economic and contextual factors. β_i is co-efficient of unknown parameters and α is the intercept, e_i is the error term. A total of five independent variables are used in the model to check their association and effect. All of them have been converted into binary forms. Depth of groundwater has been classified into two viz. below 100 ft. =1 and others into another category. In case of village, we have taken Mawi Kalan (i.e. the most vulnerable village as per our data findings) as one group and all other sampled villages as another. Caste is divided into classes viz. 1= OBC and 0= other caste categories. Similarly, educational qualification of the head is classified into two categories i.e. illiterate and literate. The households have also been classified on income basis i.e. bottom 60 percent of the household into one category whereas rest 40 percent belongs to other. Family size has also been divided into two i.e. one category includes upto 5 members in a family while more than 5 in another.

The outcomes (table 6.15) disclose that depth of groundwater and income are positively related to incidence of illness in the household. However, caste, education and family size are negatively related with health hazard within the household. Interpreting the coefficients value, it is observed that household residing in an area where depth of groundwater is below 100ft. then the log odds of household having a patient with water-related disease increases by 0.69. The value of odd ratio confirms that a household having a patient with water related illnesses is 2.001 times higher if the family units live in land area where water table is beneath 100 ft than that of above 100ft. It can be inferred from this that as water table goes down the level of groundwater contamination increases. Therefore, consumption of such water for drinking, irrigation or other purposes affects human health adversely. Thinking about the impact of education on occurrence of illness, the results demonstrate that if the leader of the family unit is literate, then the log odds of having a person in the family suffering from water-related disease decrease by 0.69. The odds ratio in this context depict that there are 0.50 times less chances of individual experiencing such infections as he/she might have general mindfulness about health aspects. To the extent social category is concerned, the coefficient value depict that the log odds of person suffering from water related health issues decrease by 1.02 if he/she belongs to OBC category. The odds ratio of 0.35 recommends that the likelihood of family units to have a patient with water related illness is higher in different classes however not in OBC classification. The socio-economic condition of OBC category in our study region is relatively better than other class which is one of the reasons for their better position with regard to health status. Interpreting the coefficients value with reference to income variable show that if household falls in bottom 60 percent category then the log odds of household having a patient with water-related disease increases by 0.72. Analysing the odds ratio, it is seen that family units having a place with the lower 60 percent income category have 2.069 times higher chances to experience the ill effects of water related ailments. Low economic status has implications on overall condition of an individual or household. Family size has additionally been considered as a determinant of sickness. The log odds of suffering from water related disease decrease by 0.65 if there are just upto five members and not otherwise. The odds ratio outcomes demonstrate that families with in excess of five individuals have 0.52 higher chances of having people who experience the ill effects of water related ailment.

The results of the logistic regression confirm that the model is statistically significant as log likelihood is -181.86 and chi2 is 49.54. Further, the z values of all coefficients are statistically significant (table 6.15).

Table 6.15: Results of Logistic Regression for Determining Incidence of Water Related Illness

Variables	Description of Variables	Coefficient Value	Z Value	p -Value	Odds Ratio
Depth of Groundwater	Below 100 ft=1 Others=0	0.69	2.69	0.00	2.00
Education	Literate=1 Illiterate=0	-0.69	-2.36	0.01	0.50
Caste	OBC=1, Other=0	-1.02	-3.95	0.00	0.35
Income	Lower 60 percent=1, Others=0	0.72	2.79	0.00	2.06
Family Size	Upto 5 members=1 Others=0	-0.65	-2.39	0.01	0.52
Constant		0.80	2.10	0.03	2.24
Loglikelihood	-181.86				
Observations	300				
LR chi2(8)	49.54				
Pseudo R2	0.11				

Source- Estimated from Field Survey Data
Note: Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$

6.5. Ground Water Stress Index (GWSI)

Ground Water Stress Index (GWSI) is developed by taking a large number of variables which indicate groundwater scarcity and pollution in an indirect or direct way. A total of 13 indicators have been incorporated to construct this index viz. drying of ponds and wells, queuing at public taps, purchase of water from private vendors, breakdown in public supply, potability of water, water related illness, rising costs of supply and treatment, abandonment of private borewell, relocation of farming to more water abundant area, falling production/ productivity levels, increase in expenditure on irrigation, fluctuations in land prices over years due to water shortages and increase in price of land which has a irrigation source.

Ground Water Stress Index (GWSI) is constructed by using Iyengar and Sudarshan (1982) methodology, wherein the selected indicators have been normalized within the range of 0-

1. Making an assessment of the qualitative indicators is tough without converting them into a specific scale so minimum and maximum values (goalposts) are set on a scale of 0 to 1.

After this step, index is generated by summing up individual score and dividing it by number of indicators**.** The result of Ground Water Stress index (shown in table 6.16) suggest that Gurana village is relatively less vulnerable with a total score of 0.79 and 0.26 as per relative and weighted index respectively followed by Vazidpur (relative index 0.38; weighted index 0.23), Pura Mahadev(relative index 0.32; weighted index 0.18) and Mawi Kalan(relative index 0.29; weighted index 0.17). The reasons for high score of Gurana are that the water table decline is lower as compared to Pura Mahadev and Mawi Kalan. The groundwater levels are lowest in Mawi Kalan and Pura Mahadev. Both these villages fall in over-exploited blocks i.e. Binauli and Pilana while Gurana and Vazidpur are in semi critical block i.e. Baraut. The average water depth is 70 ft. in Gurana, 80 ft. in Vazidpur, 100 ft.in Pura Mahadev and 120 ft. in Mawi Kalan. The dependency of farmers on groundwater has increased rapidly in all the villages with drying of public tubewells, rivers and canals over the period. Majority of the respondents in Mawi Kalan and Pura Mahadev responded that the groundwater is dirty, yellow in colour and smells foul. Further, it is also observed that the incidence of water related illness is relatively higher in Pura Mahadev and Mawi Kalan in comparison to Gurana and Vazidpur.

Table 6.16: Village wise Ground Water Stress Index

Village	Groundwater Stress Score* Relative Index	Groundwater Stress Score* Weighted Index	Rank
Gurana	0.42	0.26	1
Vazidpur	0.38	0.23	2
Pura Mahadev	0.32	0.18	3
Mawi Kalan	0.29	0.17	4

*Score near to 1 indicates low stress while closer to 0 indicates high stress
Source- Estimated from Field Survey data

In order to estimate the stress level as per the land size groups table has been presented in table 6.17. The results of Groundwater Stress Index as per land Size group suggest that stress is highest for marginal farmers i.e. 0.36 and 0.20 according to relative and weighted index while lowest for the large farmers with rank 4th and scores 0.43 (relative index) and 0.26 (weighted index). The reasons for groundwater stress to be high for marginal farmers can be deciphered from previous tables. A large number of marginal famers in the sampled villages do not possess submersible pumps and therefore have to depend either upon government supply or purchase water from other farmers for domestic as well as irrigation use. Small/marginal farmers lack income and incentive to invest in water extraction machinery thereby raising their vulnerability. The data from the below tables show that land ownership status largely influence equity in groundwater accessibility. Respondents strongly stated that land rights, insufficient government support and economic backwardness are some major obstacles behind water insecurity among small/marginal land size class. Further, consumption of polluted water has become a major cause of health issues in small/marginal farmer households and has lead to reporting of higher number of cases of water related diseases.

Table 6.17: Land Size wise Ground Water Stress Index

Land Size	Groundwater Stress Score* Relative Index	Rank	Groundwater Stress Score* Weighted Index	Rank
Marginal	0.36	2	0.20	4
Small	0.36	3	0.22	2
Medium	0.33	4	0.21	3
Large	0.43	1	0.26	1

*Score near to 1 indicates low stress while closer to 0 indicates high stress
Source: Estimated from Field Survey

6.6. Conclusion

This chapter encapsulates the details about groundwater accessibility, scarcity and stress levels in the sampled villages and shows that the problem of groundwater depletion and degradation persist in all villages but is relatively higher in Pura Mahadev and Mawi Kalan. High penetration of submersible pumpsets and unsustainable water usage pattern are key drivers behind receding water tables. The apparent danger levels rising due to digging deeper wells or boring more wells by a neighboring farmer is viewed as progressively irksome by farmers in these villages which show their intolerance towards sharing of groundwater. Further, the social appraisal of farmers reveals that they are largely driven by self interest which might in some near future lead to "Tragedy of the Commons". Further, the study shows that the incidence of water related diseases is higher in the area (Mawi Kalan and Pura Mahadev) wherein water table is low. Low water table is related with groundwater contamination thereby deteriorating its quality which ultimately results in huge impact on human health, agriculture production, productivity and economy as a whole. The consumption of polluted water has become a major cause of health issues in small/marginal farmer households living in the sampled villages and has lead to reporting of higher number of cases of water related diseases.

Chapter VII

Willingness to Pay for Managing Groundwater by Farmer Households

7.0. Introduction

Welfare economics had established that market prices are conceptually the correct measure of the economic value of a marginal change in the supply of a marketed economy. However, valuing a product which does not have a market, is freely available and excludes no one from consumption and its consumption is non rival in nature i.e. environmental goods and services is a tough task. Moreover, with humankind's awareness about the importance of natural resources and threats from its depletion/degradation, environmental economists started off with environmental valuation. Valuation can simply be defined "*as an attempt to put monetary values or to environmental goods and services or natural resources"*. It is a key exercise in economic analysis and its results provide important information about values of environmental goods and services. According to Dixon (2008, p.1), in order to value these environmental goods and services, economists have developed a whole "tool box" of valuation techniques. One general typology of these techniques is a)techniques based on changes in production or productivity, such as in the case of agricultural lands, forestry, fisheries or human health; b)Techniques that use survey-based information to estimate values; these "stated preference" techniques are usually referred to as contingent valuation methods (CVM); c) "Revealed preference" techniques that use hedonic markets to estimate values; these include property value approaches and land value approaches; d) Surrogate market approaches, such as the travel cost method (another revealed preference approach). All of these techniques are well developed, commonly used, and quite robust. Many, even thousands, of examples exist of their use. By use of these approaches, we can measure all or part of the value of different environmental resources. Harold Hotelling could be credited with highlighting a valuation technique now called "travel cost method". He used this method in 1947 to estimate the worth of national parks in United States. Several studies using various types of revealed and stated preference methods have been conducted since then. The conceptual framework for evaluation of 'non-market services' was developed by Ciriacy-Wantrup (1947, p.1181). His idea of an estimation of social benefits by questioning the public (a technique used in Contigent Valuation Method (CVM) was first put into practice by Davis (1963). Further, Richard Carson & colleagues in the year 1989 used Willingness to Pay (WTP) technique to focus on the nonuse values of the general public and measured their WTP for avoiding an accident (Pearce, 2002, pp.70-71).

Based on the background of methods of valuation of natural resources, this chapter is designed to present an outline of contingent valuation method using willingness to pay (WTP) approach and to estimate the WTP of farmer households (in our sample) for managing groundwater resources in the region as well as the factors influencing it. In order to satiate these objectives, literature review on economic valuation, contingent valuation method and WTP approach has been done and studies showcasing the determinants of WTP has also been presented. Further, using primary data, an attempt has been made to quantify the WTP for improved groundwater situation in the sampled villages. Besides, we have investigated the determinants of their WTP as a way to test the internal validity of the measure. A Logistic regression model is fitted to the data collected in order to generate predictive models of WTP.

7.1. Contingent Valuation Method

CVM is a survey method in which respondents are asked how much they are willing to pay for the use or conservation of natural goods. Their stated preferences are assumed to be contingent upon the alternative goods that are offered in a 'hypothetical market' (Zanni & Smith, 2002, p.14). Essential elements of the survey are basically the description of the natural good that is to be valued, payment vehicle and elaboration of the hypothetical market. Describing the natural goods includes identifying all valuable attributes of the goods. The payment vehicle pertains to how the money is to be paid. One can pay for a good in cash or digitally every time it is used or by means of an increased income tax. The description of the hypothetical market should include an identification of who will provide and who will pay for the nature improvement. It should be made clear that the payment is a collective action; everybody else will also pay, otherwise respondents may refuse to pay although they appreciate the good. Respondents should also be reminded of the possibility of spending their income on goods other than nature, to prevent overestimates (Hoevenagel, 1994, p.195). CVM measures benefit-based preferences and it includes the consumers' surplus. It is said to be an appropriate economic valuation method for environmental goods that have no indirect effects on other goods. It is therefore suited for the valuation of amenities or other easy to perceive aspects of nature, but not for the valuation of natural processes, such as climate regulation, where effects on human welfare are difficult to grasp. Taking account of the restrictions of valuation experience and commodity resemblance, it seems that CVM is most accurate for the valuation of publicly-managed goods with private characteristics such as natural sites. In Contingent Valuation Surveys one can encounter various sources of bias, such as samples which are not representative, strategic behaviour of respondents or confusion about the size of the good that is to be valued.

There are several approaches to estimate WTP. Direct and indirect surveys are used to collect the relevant data. In contrast to revealed preferences, preference data derived from surveys are frequently referred to as stated preferences. With direct surveys, respondents (e.g., selected customers) are asked to state how much they would be willing to pay for some product. In indirect surveys some sort of rating or ranking procedure for different products is applied in order to estimate a preference structure from which WTP can be derived. Conjoint analysis and discrete choice analysis are examples of indirect surveying methods. Miller et. al.(2011, pp.172-173), in their paper stated that there are many methods to assess WTP viz. open ended question format, choice based conjoint analysis, Beker Degroot & Marschack incentive compatible mechanism and incentive aligned choice based conjoint analysis.

Carson et.al.(2000, p.9) stated that the common approach to most applications of Contingent Valuation Surveys are: (1) an introductory section which helps set the general context for the decision to be made; (2) a detailed description of the good to be offered to the respondent; (3) the institutional setting in which the good will be provided; (4) the manner in which the good will be paid for; (5) a method by which the survey elicits the respondent's preferences with respect to the good; (6) debriefing questions about why respondents answered certain questions the way that they did; and (7) the collection of a set of respondent characteristics including attitudes, debriefing questions, and demographic information. To a large degree, the variations among CV surveys involve different techniques for eliciting respondents' preferences concerning the good of interest.

7.2. Application of Willingness to Pay in Environmental Valuation of Groundwater

Vo & Huynh (2017, p.421) in their study used the approach of CVM to analyze the households' motivations and their WTP for the program of groundwater protection in the Mekong Delta. The study performed revealed that the residents in the delta were willing to pay approximately 141,730 VND (US$6.74) per household a year. Groundwater could be an inferior good with the negative income effect found in the demanding for clean groundwater. Further, regarding the consumers' willingness to pay (WTP) for piped water supply for the Pavlodar Region, Kazakhstan showed that households with access to groundwater (well or borehole water users) perceived this as of good quality. Consumers without access to groundwater used open-source, standpipe or delivered water for which they had to travel and spend time or to pay. Open source water and standpipe water quality was perceived as bad or satisfactory. More than 90 percent of the consumers were willing to pay for better water quality and regular water supply. The mean WTP was estimated to be about 1120 in bids and about 1590 KZT per household per month in open-ended question format (Tussopova et. al., 2015, p.1).

Tang et.al. (2013, p.76) in their paper presented the results of rural household’s WTP for irrigation water in Shiyang River basin region of Northwest China. The estimation shows that the average WTP for irrigation water is 80.4 RMB/mu/yr and is substantially higher than current irrigation water price (58 RMB/mu/yr). Explanatory factors such as bid level, family size, household’s income, area of irrigation land, the major source of irrigation water, respondents’ satisfaction with the management and the farmers’ attitude towards whether current waters price could recover the water supply cost, included in the model turned out to be statistically significant.

Paz & Perni (2011, p.603) in their study entitled “Environmental Cost of Groundwater: A contingent Valuation Approach” using Contingent Valuation method found that majority of the people were ready to pay to improvise the groundwater stress and their mean WTP was 23.5 pound per year. Further, the results from Tobit model show that people with higher income are more willing to pay for improving and preserving the wetland and it can also deduced that both age and gender of respondents had a statistically significant and positive effect on the household’s WTP.

Abedi et.al. (2014, p.213) in their study “Groundwater Valuation and Quality Preservation in Iran: The Case of Yazd” calculated the willingness to pay preserving the groundwater quality in Yazd region of Iran. The monthly amount the people of Yazd were willing to pay for preservation of the quality of Yazd groundwater was US$ 852,233, which is a significant value. They further argued that improvement of the quality of water and preservation of water is more important to the heads of families and hence their WTP was closer to reality. The positive sign indicates an increase in the possibility of acceptance of the WTP for preservation and maintenance of water quality with increases in income.

7.3. Willingness to Pay among Sample Households

As discussed above, the survey method has been used in this study to estimate the household's Willingness to pay for managing groundwater in the sampled villages. The survey was conducted in four villages viz. Gurana, Vazidpur, Pura Mahadev and Mawi Kalan of Baghpat district by means of face to face interview to randomly selected 300 households. They were given a description of a hypothetical scenario wherein the government will initiate a groundwater management plan which will try to fulfill the irrigation needs of the farmers and lower their cost of irrigation. This will directly as well as indirectly help the entire population in the region to have access to sufficient and quality water. This plan would include a series of actions which would help reduce water footprint of the households and increase the groundwater stock so as to make it available to future generations. As citizens of this region would benefit from initiation of such plan, the government may ask them to contribute in monetary terms.

Based on this hypothetical market, respondents were asked to elicit their willingness to pay. The response was usually taken from head of the households who has the main decision power in the household and also has knowledge about the contextual conditions. The questions were specifically targeted to decipher the WTP, the amount he/she is willing to pay and the primary reasons for paying or not paying. Table 7.1 depicts that overall out of 300 respondents, 79 percent stated positive WTP and 21 percent negative WTP. Positive WTP means that the respondents were interested in improvising the situation while negative WTP refers to the opposite. In Gurana, 66.67 percent said that they are willing to pay for promoting groundwater management in their area while 33.33 percent said that they are not willing to contribute anything financially. In Vazidpur, 78.67 percent agreed to contribute in any improvement strategy for groundwater management in the area while 21.33 percent did not. In Pura Mahadev, majority of the respondents agreed and were willing to pay for improving the groundwater scenario while 16 percent denied. In Mawi Kalan, 86.67 percent said that they are interested to pay but 13.33 percent stated otherwise. As our study is confined to farmer households, considering land ownership wise behaviour regarding WTP is also necessary. Focusing now on the land size group (Appendices, table 7.1A) behaviour regarding willingness to pay for ground water management it was found that in marginal farm size group 81.36 percent agreed while 18.64 percent disagreed. In small farm size group, 67.09 percent said that they are ready to contribute but 32.91 percent did not. In medium category, 92.50 percent agreed while 7.90

percent denied while in large category 75 percent stated that they are willing to pay but 25percent answered negatively.

Table 7.1: Village wise Willingness to Pay –Yes/No

Village	Yes	No	Total
Gurana	50 66.67* 21.1**	25 33.33* 39.68**	75 100* 25**
Vazidpur	59 78.67* 24.89**	16 21.33* 25.4**	75 100* 25**
Pura-Mahadev	63 84* 26.58**	12 16* 19.05**	75 100* 25**
Mawi Kalan	65 86.67* 27.43**	10 13.33* 15.87**	75 100* 25**
Total	237 79* 100**	63 21* 100**	300 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage **column percentage; Pearson chi2(3) = 10.66 Pr = 0.01

Dwelling deeper into the matter, the respondents were asked about the amount they are willing to pay on monthly basis for managing groundwater. Table 7.2 shows that overall out of the 237 respondents who agreed to pay for improvising the groundwater situation 24.89 percent said they would pay upto Rs. 25, 21.52 percent respondents agreed to pay Rs.100 per month. The percent of households agreeing to pay Rs.125per month is 20.25 percent while 19.83percent are willing to pay rs.75 per month and 13.50 percent upto Rs.30 per month. In Gurana, 52 percent out of the total respondents in the village are willing to pay Rs.25per month, 24 percent upto Rs.50 per month, 12 percent upto Rs.75 per month, 8 percent upto Rs.100 and 4 percent agreed to pay Rs. 125 per month. In Vazidpur 27.12 percent agreed to pay Rs.25 per month , 18.64 percent upto Rs.50 per month, 16.95 percent Rs.75 per month, 20.34 percent upto Rs.100 per month and 16.95 Rs 125 per month. In Pura Mahadev 12.70 percent agreed to pay Rs.25per month , 14.29 percent are willing to pay Rs 50 per month, 25.40 percent upto Rs.75per month, 30.16 percent upto Rs.100 per month and 17.46 percent upto Rs.125 per month. In Mawi Kalan 13.85 percent are willing to pay Rs25 per month, 23.08 percent are willing to pay Rs. 75 per month. The percent of respondents willing to pay Rs.100 per month is 24.62 percent while 38.46 percent agreed to pay Rs.125 per month. The percent of respondents in the Rs.25 per month block of WTP is highest in Gurana because the groundwater situation is relatively less grave as compared to Pura Mahadev and Mawi Kalan. The ground water depth is 70 feet in Gurana while it is more than 100 feet in Pura Mahadev and Mawi Kalan. Therefore the respondents do not feel so much of need and motivation to pay a higher amount. Almost a similar condition prevails in Vazidpur wherein the decline in groundwater level is not so rapid and the situation is better than Pura Mahadev and Mawi Kalan. An important point to mention over here is that according to CGWB, Vazidpur and Gurana are part of Baraut Tehsil which comes under the semi- critical category with reference to groundwater development. Thus, one may infer that the reason behind low financial contribution response by farmers in Gurana and Vazidpur is better hydrological conditions. Land size wise analysis (Appendices, table 7.2A) shows that in marginal category, the majority i.e. 31.25 percent are willing to pay Rs.25 per month while 17.36 upto Rs. 125 per month. In small farm size group, the larger proportion agrees to pay upto Rs 125 per month. In medium land size group, 32.43 percent agreed to pay Rs.100 per month and 21.62 percent upto Rs. 125 per month. In large farm size category, 66.67 percent are willing to pay Rs100 per month per month while 33.33 percent upto Rs. 125 per month. Therefore, we observe that WTP is higher among medium and large category farmers.

Table 7.2: Village wise Monthly Amount that Respondents like to pay

Village	Rs.25	Rs.50	Rs.75	Rs.100	Rs.125 & above	Total
Gurana	26 52* 44.07**	12 24* 37.5**	6 12* 12.77**	4 8* 7.84**	2 4* 4.17**	50 100* 21.1**
Vazidpur	16 27.12* 27.12**	11 18.64* 34.38**	10 16.95* 21.28**	12 20.34* 23.53**	10 16.95* 20.83**	59 100* 24.89**
Pura-Mahadev	8 12.7* 13.56**	9 14.29* 28.13**	16 25.4* 34.04**	19 30.16* 37.25**	11 17.46* 22.92**	63 100* 26.58**
Mawi Kalan	9 13.85* 15.25**	0 0* 0**	15 23.08* 31.91**	16 24.62* 31.37**	25 38.46* 52.08**	65 100* 27.43**

Total	59 24.89* 100**	32 13.5* 100**	47 19.83* 100**	51 21.52* 100**	48 20.25* 100**	237 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage **column percentage; Pearson chi2(15) = 71.98 Pr = 0.00

After an analysis about the amount that the farmers are willing to contribute to solve the groundwater situation in the region Table 7.3 has been prepared to present the most important reason behind their willingness. In Gurana, 48 percent farmers believed that solving the current water crisis is the primary reason while 20 percent considered mitigating future water shortage as the major reason. In Vazidpur 35.89 percent revealed that their prime motive behind contributing financially is to solve the current water crisis and 20.34 percent said that it is due to high current water expenditure. In Vazidpur 18.64 percent said that this would also coerce cooperation / regulation in groundwater use. In Pura Mahadev the major reason is solving the current water crisis and 30.16 percent said it will be helpful in promoting regulation in use. In Mawi Kalan 58.46 percent said that the ultimate objective behind financial contribution is to solve the existent water stress while 21.54 percent termed current water expenditure to be the first reason. Overall the majority responded that solving the current water situation is the main motive for contributing in financial terms. Taking into account the land size group responses (Appendices, table 7.3A), it is witnessed that the major reason behind financial contribution is to solve the current water crisis across all farm-size owners.

Table 7.3: Village wise Primary Reason for Willingness to Pay

Village	For Solving Current Crisis	For Solving Future Shortages	Current Expenditure Is high	Water is a right	Good Cause	Coerce Cooperation	Total
Gurana	24 48* 21.62**	10 20* 33.33**	7 14* 16.28**	5 10* 38.46**	3 6* 37.5**	1 2* 3.13**	50 100* 21.1**
Vazidpur	21 35.59* 18.92**	9 15.25* 30**	12 20.34* 27.91**	2 3.39* 15.38**	4 6.78* 50**	11 18.64* 34.38**	59 100* 24.89**
Pura-Mahadev	28 44.44* 25.23**	3 4.76* 10**	10 15.87* 23.26**	3 4.76* 23.08**	0 0* 0**	19 30.16* 59.38**	63 100* 26.58**

Mawi Kalan	38 58.46* 34.23**	8 12.31* 26.67**	14 21.54* 32.56**	3 4.62* 23.08**	1 1.54* 12.5**	1 1.54* 3.13**	65 100* 27.43**
Total	111 46.84* 100**	30 12.66* 100**	43 18.14* 100**	13 5.49* 100**	8 3.38* 100**	32 13.5* 100**	237 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage **column percentage; Pearson chi2(15) = 44.52 Pr = 0.00

Coming to the answers behind unwillingness to pay, table 7.4 throws light on the village wise primary reason for unwillingness to pay. In Gurana, 60 percent of the respondents who were not willing to pay anything was due to the reason that their believed that the government should pay. In Vazidpur, an equal percent i.e. 31.25 percent considered that water security is the government's responsibility and there is no need to pay because current water consumption is met. In Pura Mahadev, a large number of respondents 66.67 percent considered that groundwater management is the sole responsibility of the government. In Mawi Kalan, 60 percent of the respondents said they would not pay because they do not have sufficient income. Land size wise (appendices, table 7.4A) analysis shows that in marginal category, 33.33 percent respondents said they are not willing to pay because they do not possess enough income. In small category 61.54 percent said that they are not interested in paying because they consider it to be government responsibility. In medium category all the respondents who are not WTP think that it is duty of the government and likewise in large category.

Table 7.4: Village wise Primary Reason for Unwillingness to Pay

Village	No Current Severe Crisis	No worry About Future	Expenditure is too high	Insufficient Income	Govt. Should Pay	Other	Total
Gurana	0 0* 0**	5 20* 45.45**	1 4* 25**	3 12* 21.43**	15 60* 51.72**	1 4* 25**	25 100* 39.68**
Vazidpur	1 6.25* 100**	5 31.25* 45.45**	2 12.5* 50**	2 12.5* 14.29**	5 31.25* 17.24**	1 6.25* 25**	16 100* 25.4**
Pura-Mahadev	0 0* 0**	0 0* 0**	0 0* 0**	3 25* 21.43**	8 66.67* 27.59**	1 8.33* 25**	12 100* 19.05**

Mawi Kalan	0 0* 0**	1 10* 9.09**	1 10* 25**	6 60* 42.86**	1 10* 3.45**	1 10* 25**	10 100* 15.87**
Total	1 1.59* 100**	11 17.46* 100**	4 6.35* 100**	14 22.22* 100**	29 46.03* 100**	4 6.35* 100**	63 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage **column percentage; Pearson chi2(15) = 23.90 Pr = 0.06

All the above tables suggest that the intensity of groundwater problem is high across all sampled villages and the heat is felt equally by all land size groups as majority (79 percent) is willing to pay for groundwater management. People are willing to contribute a high amount of Rs.100 or Rs.125 to solve the present water crisis in the region and also to preserve the valuable resource for future generations.

7.4. Factors influencing Willingness to Pay

Willingness to pay for environmental purposes is influenced by a large number of factors viz. socio-economic, geographical, psychological etc. Studies using contingent valuation method to elicit WTP have considered all the above stated factors as per their objectives and need. Dika & Birhane (2019, p.1) employed contingent valuation method was employed to elicit household's willingness to pay for the proposed improvement in solid waste management services in Gulele Sub-City, Wereda 3, Addis Ababa, Ethiopia. The dependent variable in their study was WTP (Yes/No) and age, household income and household size. The study concluded that household WTP is positively affected by household size and is significant while age of the head, education level show statistically insignificant and negative relationship. Considering income of the household the study's result depict a positive but statistically insignificant association.

According to Naanwaab et.al. (2014, p.2793) in their study on Evaluation of consumers' perception and willingness to pay for bacteriophage treated fresh produce, willingness to pay does not vary substantially with education level. Based on the estimation results, income was found to be the most significant determining factor of a consumer's WTP. Furthermore, the logistic analysis showed that a consumer's race and their State of residence were also significant in determining that individual's willingness to pay an additional amount for fresh produce treated with bacteriophage as preservative.

In a study by Vo & Huynh (2017, p.421) on "Estimating residents' willingness to pay for groundwater protection in the Vietnamese Mekong Delta", all of the estimators household income, respondent's gender and education status were significantly exogenous variables affecting the WTP response. The relationship with all variables except income had contrary results i.e. it had a negative association with groundwater protection. The authors explained it as follows-"if it is not difficult to get clean water from the tube well or is easy to buy from the GSU, it is a normal good. In this context, the relationship between the household income and the demand for clean water (by voting for the GPP) is positive. Conversely, if the possibility of assessing the clean groundwater is at the edge of the risk, for instance, due to contamination, it could be an inferior good. In this case, as the prediction of demand theory, the demand for groundwater protection decreases as household income increases. Possible explanation could be that respondents with high income who prefer safe and clean water (tap water) consider groundwater as an inferior good. Besides household income, respondent's gender and education status were significantly exogenous variables affecting the WTP response".

Study by Venkatachalam (2014, p.134) showed that the insignificant difference in mean WTP across income categories suggests that the income difference among households does not influence WTP significantly.

Biswas (2015, p.1) in the study titled "Farmers' Willingness to Pay for Improved Irrigation Water-A Case Study of Malaprabha Irrigation Project in Karnataka, India" focused upon the standard socio-economic factors viz. education, gender, caste and age of the respondent. Although many CV studies on drinking water supply found that the WTP was positively influenced by education in this study its influence was ambiguous. In the case of gender, previous studies revealed mixed outcomes (Weldesilassie et al., 2009, p.428; Tang et. al. 2013, p.76). Owing to the "masculine" nature of irrigation practices (Zwarteveen , 2011, p.40) and the fact that women negotiate financial and agricultural decisions within complex and dynamic social situations, no specific direction between gender and WTP values was expected. Age was expected to bear a positive influence on the WTP because with age, farmers gain more experience in agriculture and are able to perceive the benefits of improvements in canal water supply. Further, influence of location (ZONE) of the villages on the WTP value was indeed significant and farmers who faced high scarcity (Zone A) were willing to pay significantly higher than those farmers in Zone B. The estimated marginal effects model shows that the probability of a yes response from farmers in Zone A is nearly 0.42 percentage points higher than the probability of a yes response from farmers in Zone B (Table 8). The influence of income generated from the sale of crops on WTP value was positive and highly significant; it indicates that as a farmer's expected benefit increases, WTP also increases.

Fentaw and Mezengo (2018, p.1) in their study on "Household's demand for groundwater conservation: The case of irrigation practices in Kombolcha district, Eastern Ethiopia" determined that monthly income, educational level, total farm land holding, total family size, perception and tropical livestock unit were variables that have significant effect on households' willingness to pay. Thus, socio-economic variables should also be considered while designing water related projects at household level.

Knapp (2016, pp.1-4) conducted a research study on "Willingness to Pay for Irrigation Water under Scarcity Conditions" in Arkansas Delta region. He assessed the impact of various factors on individual's WTP, however out of the total 14 variables were found to be statistically significant. The bid value, awareness of state tax credit, if county of residence east of Crowley's Ridge, participation in the CRP, perception of groundwater shortage, years farming and its squared term, gross income and its squared term, cotton acres, percent of cotton acres and rice acres all have statistically significant impacts on WTP.

Considering the social, economic, agriculture production and geographic conditions, we have estimated the factors influencing willingness to pay among farmers households within the surveyed area. Social factors viz. age of the respondent, caste and his/her educational qualification has been included. Total household income (farming, livestock and other sources), land size and agricultural output are incorporated in the category of economic variables. Geographical and hydrological differences also matter in our study so type of village, groundwater stress level has also been added as variables.

As per the literature review and descriptive statistics a table has been designed below to present the hypothesis for the independent variables in the logistic regression (table 7.5). Age and education level of the respondent are considered to have a positive and significant effect on WTP for managing groundwater. It is expected that older citizens are more mature decisions related to evaluating health and environmental issues, possibly due to their age, leading them to express high willingness to pay value. It is believed that as the education level increases so is the capacity of the people to become more knowledgeable on environment protection. A study conducted in Oyo State, Nigeria, also showed that level of education influences accountability of extension services (Omotesho et al., 2015, p.94). Taking into account the economic variables, land size (if large), income and output are considered to depict a positive and significant relationship. A positive correlation between the land amount and WTP has been identified, therefore when the amount of land increases, WTP increases too (Aydogdu, 2017, p.785). In our study, we have used marginal land size group as reference category so we expect a negative association with high value of WTP. As far as income is concerned, generally, there is a general agreement in the environmental economics literature on the positive relationship between income of the head of the household from all sources and demand for improvement in environmental quality. Therefore, we expect the income to affect the willingness to pay and its amount positively. Further, agriculture output is taken as an indicator of farmer's economic well being and production trends. Hydrogeological indicators viz. location of the farmer (i.e. village) and groundwater stress index have been undertaken as determinants of WTP.

Table 7.5: Hypotheses for Covariates

Variables	Null Hypothesis/ Expected Sign
Caste	-ive & Significant
Age of the respondent	+ive & Significant
Education of the respondent	+ive &Significant
Land Size	-ive &Significant
Total Household Income	+ive & Significant
Agriculture Output	+ive &Significant
Village of Residence	+ive & Significant
Groundwater Stress	+ive & Significant

Source- Field Survey Data

Results of Logistic Regression

Based on the above background, the ‘willingness to pay’ for all farmer households within the surveyed area has been categorised into two groups i.e. ‘upto Rs. 50’ as one group and ‘Above Rs.50’ as another. The category of “Above Rs. 50” is the referred one and is the dependent variable in our regression model. A total of eight independent variables are used in the model to check their association and effect. All of them have been converted into binary forms. Land size groups have been divided into two viz. marginal category and other size groups are clubbed into one. In case of village, we have taken Mawi Kalan (i.e. the most vulnerable village as per our data findings) as one group and all other sampled villages as another. Age of the respondent is divided into groups one wherein the age group upto 50 years while other is above 50. Caste is divided into classes viz. 1= SC and 0= other caste categories. Similarly, educational qualification of the respondent is classified into two categories i.e. illiterate and literate. The households have also been classified on income basis i.e. bottom 60 percent of the household into one category whereas rest 40 percent belongs to other. Likewise, groundwater stress index has been arranged into two viz. high and low stressed. Further, agriculture output value is stratified as ‘upto Rs. 2 lakhs’ and ‘above Rs. 2 lakhs’.

The following logistic regression model is utilised to estimate the probability of WTP for managing groundwater by the farmer households within the sampled villages:

$$Y_i = ln\frac{P_i}{1 - P_i} = \alpha_i + \beta_i X_i + e_i$$

Wherein, Y_i=whether the farmers household’s is WTP i.e. above Rs.50 for improvement in groundwater ecosystem,

X_i = the matrix of explanatory variables comprising all social, economic factors and hydrogeological factors,

β_i=co-efficient of unknown parameters

α =intercept,

e_i = is the error term

The results of logistic regression (Table 7.6) reveal that village, agricultural output, groundwater stress have positive relation with willingness to pay while education, land size, caste and income have negative association. All the variables in the model are statistically significant except education. Considering hydrogeological factors viz. location of the village and groundwater stress level, the results show that both these variables are positively and statistically related. Analysing the relationship of village location with WTP, regression result reveal that the log odds of having WTP of more than Rs.50 increase by 0.79 if person lives in Mawi Kalan. If the household belong to Mawi Kalan village there are 4.98 times more chances that it will pay above Rs. 50 per month to solve the groundwater problem. The groundwater stress level also highly affects the WTP. Focusing on social factors viz. age and age, the coefficients value depict that log odds of higher WTP decrease by 0.57 and 1.40 if age of head is upto 50 and the household falls in SC category. The odd ratio shows that the probability of farmer household to pay 'more than Rs 50' for managing groundwater problem in the region is 0.35 times less if the respondent belongs to other caste. Considering age of the respondent, the results depict that WTP of the young person is less than an old/matured person. The odd ratio of 0.56 depict that if the respondent's age is less than 50 years there are 0.56 less chances that he/she will pay more than Rs. 50. Therefore, suggesting that age is positively related with WTP. As far as effect of education is concerned, the regression output depicts a negative and statically insignificant relationship. The odd ratio reflects that literate respondents are 0.63 times less willing to pay a higher amount for groundwater management.

Taking into account the economic factors, land size, income level and value of agriculture output all show a statistically significant association with WTP. As per our reference category in land size group i.e. marginal, the log odds of paying more than Rs.50 decrease by 0.79 and odd ratio depicts that if the household possess marginal size of land then there are 0.45 times less chances of him paying Rs. more than 50. Thereby depicting a positive and significant linkage with WTP viz. increase in farm size leads to rise in WTP. Income of the household also has a positive relationship with WTP i.e. higher income group has higher WTP. The log odds of high WTP decrease by 0.59 if households falls in bottom 60 percent income category. The odd ratio further confirms that the top 40 percent of the households (based on income) have 0.55 times more willingness to pay than the bottom 60 percent of the households. Value of agriculture output also has a positive and statistically significant association with willingness to pay i.e. if the households produce agriculture output of value above Rs. 2 lakhs then the log odds of WTP more than Rs.50 increase by 0.57 and there are 1.78 times more chances of it to pay an amount of more than Rs. 50. The locations of the farmer household, caste and groundwater stress levels are the most significant determinants of WTP in managing groundwater. The results of the logistic regression confirm that the model is statistically significant as log likelihood is -130.46 and LR chi2 is 54.67. Further, z values of all coefficients are statistically significant.

Table 7.6: Results of Logistic Regression for Determining Willingness to Pay for managing Groundwater

Variables	Description of Variables	Coefficient Value	Z value	p-Value	Odds Ratio
Land Size	Marginal=1 Others=0	-0.79** (0.37)	-2.11	0.03	0.45
Village	Mawi Kalan=1 Others=0	1.60*** (0.43)	3.73	0.00	4.98
Age of the Respondent	Upto 50 yrs=1, Others=0	-0.57* (0.31)	-1.83	0.06	0.56
Caste	SC=1, Others=0	-1.40*** (0.45)	-2.31	0.02	0.35
Educational Qualification of the Respondent	literate=1, Others=0	-0.45 (0.38)	-1.18	0.23	0.63
Income	Bottom 60 percent=1, other=0	-0.59* (0.34)	-1.71	0.08	0.55
Agri. Output	Above Rs.2Lakh=1 Below Rs.2 Lakh=0	0.57* (0.35)	1.65	0.09	1.78
Groundwater Stress	High=1, Low=0	0.75*** (0.31)	2.41	0.01	2.13
Constant		1.10* (0.60)	1.83	0.06	3.03
Log likelihood	-130.46				
Number of observation	237				
LR chi2(8)	54.74				
Pseudo R2	0.17				

Source- Estimated from field survey Data

Note: Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

7.5. Conclusion

Given the lack of quantitative studies about environmental and resource costs with clear methodology, this chapter provides an application of Contingent Valuation Method (CVM) and to captures the total economic value of groundwater especially in agriculture sector. The survey has been carried out in one of the most critical areas with reference to groundwater stress in Uttar Pradesh, therefore, the results help in highlighting that people are suffering to a large extent and it's the reason behind their high willingness to pay. The estimated results clearly show the inter-village and inter-land size differentials in WTP and suggest that the most vulnerable is the ultimate sufferer and is ready to spend a higher amount to come out of the problem. In Gurana and Vazidpur the number of people willing to pay for groundwater management is less than those in Mawi Kalan and Pura Mahadev, due to the better groundwater conditions. Considering the monthly WTP, it is observed that in Mawi Kalan and Pura Mahadev, 38.46 percent and 17.46 percent each are willing to contribute Rs 125 or above against 4 percent and 16.95 in Gurana and Vazidpur respectively. Further, the findings of this chapter are beneficial for deciphering the factors which largely affect the farmer's willingness to pay and deciding on the economic pricing of a common good like groundwater. The results of logistic regression show that land size ownership, caste, geographical condition, income, education i.e. the socio-economic characteristics play a pivotal role in an individual's attitude towards environment protection. The results clearly reflects that most of the farmers are concerned (through WTP) about groundwater depletion and water security especially the victims. As a result of absence of proper monitoring mechanism, most of them show willingness to pay to rectify the problems.

Chapter VIII

Major Findings and Policy Recommendations

8.0. Introduction

Groundwater depletion and degradation is a genuine concern for *Homo Sapiens* all across the globe. Unsustainable anthropogenic activities, lack of rules, regulations, poor and faulty management arrangements are primary reasons behind rising water stress. In this context, study has been made to feature a portion of the real drivers and effects of groundwater over abuse in India's agriculture sector and especially in Baghpat district of Uttar Pradesh. The research study utilized both primary and secondary data to examine the three different objectives of the study. Firstly, the secondary level data was utilized to assess the extent and present status of groundwater consumption and management at national, state and district level. Further, an endeavor has been made to comprehend the significant reasons for groundwater exploitation in agriculture sector in all parts of the world yet especially in India. Secondary data and literature has been broadly concentrated upon to capture the different causes and effects of groundwater scarcity. Secondly, primary data obtained from villages has been used to assess the groundwater stress level, factors arising in agriculture sector that contribute towards groundwater exhaustion and health impacts of groundwater contamination within the study area. In addition to this, an appraisal of the attitudes and behaviour of farmers towards groundwater conservation has also been examined. Thirdly, after an elaborative study of the causes and effects, suitable solutions have been provided as per the hydrogeological, socio-economic and political framework.

In the preceding chapters, introduction, review of related literature, methodology, analysis of data and interpretation of results has been presented. In this chapter, the summary and research findings related to all the chapters are described along with the policy recommendations, limitations and further scope.

8.1. Major Findings

Chapter *one* of the study titled "**Economic Development and Groundwater: Theoretical and Conceptual Framework**" is basically an attempt to highlight the importance of natural resources particularly groundwater in economic development. It focuses on the theoretical and conceptual understanding of common pool resources particularly groundwater.

First, it sets a theoretical background by presenting a brief review of scholarly work of the classical to modern day economists on the relationship between natural resource and economic well being of people and countries.

Second, it focuses on the conceptual framework of common pool resources and underlines the importance of groundwater resources for everyone and in every economic sector. It highlights that water scarcity is expected to intensify during the twenty-first century. In many regions, climate change causes scarcity to become more acute. Groundwater has the capacity to buffer extreme hydrologic events because recharge is not directly tied to precipitation and run-off events. The value of groundwater will increase as scarcity intensifies and effective groundwater management would become sine-qua-non. Groundwater management in agriculture sector in India faces a set of challenges ranging from administrative, social, economic, and political. Third, it details out the research questions, objectives and methodology of the study. It also presents a brief review of the issues pertaining to groundwater conservation in India's agriculture sector. The different challenges of groundwater management have been clubbed into several categories that include physical (cropping pattern, the number of components, climate, irrigation method, etc.), economy (finance, insurance, difficult access to inputs, etc.), social (consumer behavior, neighbors, responsibility of sponsoring, non-agricultural income, etc.) and institutional components (ownership of water resources, lack of law enforcement, rental of water resource). The chapter also entails the design of the study, sample of the study, tools used, data collection procedure followed and the statistical methods followed.

Chapter *two* titled "**Groundwater: Stress, Governance and Implications**" is an attempt to analyse the set of drivers and impacts of groundwater depletion/degradation. Groundwater depletion and degradation has massive impacts on environment, economy and human beings. An elaborative review of literature has been done in this chapter and it suggests that groundwater degradation and scarcity have implications ranging from ecological effects such as salination and desertification, to social inequalities to political challenges, as well as economic tensions.

First, the study focuses on various factors affecting groundwater use and management in agriculture sector. Institutional factors viz. common pool resource nature, land easement act[1], lack of water pricing and tax mechanism pose a challenge towards effective groundwater management. Due to the characteristics of groundwater as a common property resource and ineffective regulations, large farmers with higher pumping capacity and deeper tube wells have a disproportionate claim over the resource than others and has lead to creation of 'water markets' and exacerbated social inequity. Low private cost of using groundwater due to subsided

[1] The Easement Act, 1882 provides every landowner to collect, dispose all the water under and over the surface on his land.

electricity to agriculture sector has promoted sub-optimal use of this precious resource. Apart from this, supply side factors which include grants or low-cost loan finance for water well construction and irrigation hardware, support for the collection and dissemination of hydrogeological knowledge on groundwater occurrence and potential, technical evolution of waterwell pumps have made groundwater a likeable resource, thus, hampering its management. Intensive agriculture dominated by monoculture has led to overexploitation of natural resources particularly groundwater. In India, water-guzzling crops production viz. rice, wheat and sugarcane is extremely high and this cropping pattern has been followed since a long period which now demands a shift with rising water problems and climate change. In addition, groundwater depletion and degradation is affected by farmer ignorance, illiteracy and incomprehension towards its management and efficient use. Socio-economic condition of farmers affects groundwater management. Farmer's behaviour towards environment conservation is highly affected by socio-economic variables viz. size of land holding, educational level, off-farm income, and environmental values etc.

Second, taking into account the impacts or effects of groundwater depletion and degradation scholar opined that they also range from environmental impacts to pecuniary, social and health. Environmental implications include soil salinization, salt water and sea water intrusion, land subsidence, and drying up of lakes and vegetation in different parts of the country. Various pecuniary impacts include increased pumping costs, decreased land values, loss of rural livelihoods, high input cost, migration, social conflicts and inequalities are also very prominent. Unsustainable groundwater use can have long term impacts on agricultural production and food security. Further, groundwater contamination is a serious issue for aquatic/ocean life and human health. Drinking water containing bacteria and viruses can result in illnesses such as hepatitis, cholera, typhoid and even major problem like Methemoglobinemia or 'blue baby syndrome'.

Third, considering the governance and management of groundwater resources, literature reveals that there exist primarily two instrumental approaches i.e. assignment of regulations and water-use rights (including rules, permits, entitlements, licenses) which establish the privileges, restrictions, and obligations of groundwater users and second approach is use of pricing(includes taxation). A third and a relatively new approach is community management. The present study observed that there is no textbook solution to natural resource crisis and thus a hybrid approach which includes elements from the all the above stated approaches is a viable option.

Chapter three titled **"Groundwater: Extent and Dynamics behind its Management**" presents the status, extent and dynamics affecting management of groundwater resources across states in India. It also highlights the relationship between land distribution and groundwater accessibility.

First, through secondary level data it is clear that groundwater is the main source of irrigation and provider of drinking water in India. Agriculture sector is the primal user and so it's the responsibility of this sector to use and manage the blue gold judiciously. Regional analysis of Ground Water Resources of India reveals that North Western plain states and Western Arid region have highest groundwater development as well as have the highest share of over-exploited units. Among the states, Uttar Pradesh ranks first in terms of share of replenishable ground water resources and its stage of groundwater development is as high as 74 percent. Data evidences depict that groundwater stress has deepened over the years in Uttar Pradesh. Groundwater development is highest in Western region of the state with an average of 84.76 percent, followed by Central region (72 percent), Eastern region (70.70 percent) and Bundelkhand (65.14 percent). District wise analysis of groundwater development show that Baghpat district in Western Uttar Pradesh is the only district wherein none of the block is in safe category. Therefore, the study selected it for primary survey.

Second, this chapter tries to decipher few major factors affecting groundwater management in agriculture sector. Correlation analysis reveals that groundwater development has a positive linear correlation with population growth rate, power subsidy, NSDP growth rate, electricity consumption and Human Development scores on the contrary it possess a negative correlation with poverty, power tariff rate for agriculture sector and environmental performance score. Further, regression analysis show that a positive and statistically significant relationship exist between stage of groundwater development and population, economic growth, power subsidy and a negative relationship with poverty and power tariff.

Third, using data from four consecutive agriculture census of India viz. 2000-01, 2005-06, 2010-11 and 2015-16 the study measured the inequalities (through gini coefficients) in land distribution. Haryana and Rajasthan have highest level of inequality followed by Sikkim, Chhattisgarh, Assam, Himachal Pradesh, Karnataka Gujarat, and Uttar Pradesh also have significant level of inequality with 0.46, 0.46, 0.47 and 0.41 respectively in 2015-16. A similar trend is seen during 2010-11, 2005-06 and 2000-01. Data anatomisation suggested that land distribution is uneven in India and have remained so over time with 0.53 values in 2000-01, 0.54 in 2005-06, 0.53 in 2010-11 and 0.51 in 2015-16.

Fourth, the study tried to establish linkage between land distribution inequality and groundwater accessibility by using Minor Irrigation Census (MIC) and Agriculture Census data. An analysis of state wise percentage share of various groundwater schemes held by different farm size category from 2000-2014 found that its ownership across states is highest with medium landowners i.e. 40.53 percent on all India level, followed by small category farmers (29.49 percent) marginal farmers (26.62 percent) and large category (3.44 percent) during 2013-14. Assessing it state wise it is observed that such inequality in ownership of groundwater schemes is extremely high in Punjab, Rajasthan, Haryana and Uttar Pradesh. The gini coefficient with reference to groundwater schemes refer that inequalities are high in Uttar Pradesh wherein there has been a rise of 0.38 with Gini coefficient being 0.27 in 2000-1 and 0.65 in 2013-14. Haryana is another state whose Gini coefficient is significantly high as per 2013-14 i.e. 0.56. It is followed by Tripura (0.56), Chhattisgarh (0.37), West Bengal (0.36), Rajasthan (0.35) and so forth. Setting up a linkage between land distribution and groundwater inequities i.e. of their gini coefficients, it is deciphered that majority of the states which have a high value of gini coefficient in land distribution viz. Haryana, Rajasthan, Madhya Pradesh, Uttar Pradesh and Punjab etc. also have it in case of groundwater accessibility pattern. Thus, confirming that landholding ownership inequality has an impact on access to groundwater accessibility. In other words, land inequalities have positive relationship with inequality in groundwater accessibility.

Chapter *four* titled "**Socio-Economic Profile of Baghpat, Uttar Pradesh**" presents the social and economic status of sampled farmer households in different villages.

First, Gurana and Vazidpur villages have households with relatively better off socio-economic condition than Pura Mahadev and Mawi Kalan. However, there are certain variables wherein no inter-villages differentials could be seen. All the villages have predominance of 'Jat' community and they are the ones who are better off with reference to all indicators. Overall, a trend of higher family size with increase in landholding ownership could be seen but majorly a nuclear family structure is witnessed across all villages. Most of the people could afford to live in a pucca house and a small percentage resides in a katchha type of house structure.

Second, considering education level, data analysis indicate that Gurana and Vazidpur are better in terms of education level as the percentage of illiterates is lower in these villages. Taking into account the employment and income pattern, it is found that unemployment is high in Pura Mahadev and Mawi Kalan while low in Gurana and Vazidpur. Households in Gurana, Vazidpur have lower proportion of people depending upon secondary source of income. The mean income of households in Gurana village is Rs. 6, 57,017, highest in all four villages, followed by Mawi Kalan (Rs. 4, 57, 170), Vazidpur (Rs. 4, 46, 874) and Pura Mahadev (Rs. 4, 41, 615).

Third, an assessment of groundwater levels across the villages found that water depth is much lower in Pura Mahadev and Mawi Kalan, ranging from 100-140 feet than in Gurana and Vazidpur (70-90 feet). Due to extremely low levels of water table, a larger share of population in these villages depend upon submersibles/electric motors for abstracting water for domestic use while in Gurana and Vazidpur still a significant proportion of population thrives on water from other sources viz. hand pump and piped water supply.

Further, the result of Socio-Economic Vulnerability Index show that Gurana village is relatively less vulnerable with a total score of 0.79 followed by Vazidpur (0.70), Pura Mahadev (0.27) and Mawi Kalan (0.19).

Chapter *five* titled "**The Various Dimensions of Agriculture in the Surveyed Area**" made an attempt to observe India's agrarian crisis through the lens of primary data collected from different villages of Baghpat district, Uttar Pradesh.

First, the data show that total production of wheat is highest for Mawi Kalan followed by Gurana, Vazidpur and Pura Mahadev. Small and marginal farmers together produce 65.08 percent of wheat in Gurana, 65.17 percent in Vazidpur, 74.45 percent in Pura Mahadev and 65.35 in Mawi Kalan. This confirms the general view that small farmers are necessary for food security and their contribution in production is the most significant. Analysing productivity levels of wheat village wise it is found that higher levels of productivity exist in Vazidpur and Gurana and small farmers are more productive. As far as sugarcane production is considered, data shows that it is highest in Gurana followed by Vazidpur, Pura Mahadev and Mawi Kalan. Average productivity trends show that sugarcane crop yields is higher in case of marginal and small farmers.

Second, we have attempted to calculate the cost of cultivation under sugarcane and wheat cropping system among different farm size categories in all sampled villages. Inter village comparison explains that the total cost of cultivation in marginal category is highest in Mawi Kalan i.e. Rs. 84959.33 per acre followed by Pura Mahadev (Rs.79720.4/acre), Vazidpur (Rs.79635.3/acre) and Gurana (Rs.77308/acre). A similar trend is observed in all land size categories. Considering the net returns, data reveals that across all land size, farmers in Gurana earn the maximum profit except in case of medium landholder wherein Mawi Kalan leads and is trailed by Gurana, Pura Mahadev and Vazidpur. Inter-farm size analysis suggests that marginal farmers in all villages bear the highest cost of cultivation followed by small, medium and large farmers. The highest share of their expenditure is incurred on imputed value of family labour (approx. 30 percent) followed by hired labour (ranging from 10-15 percent), electricity (10 percent), fertilizers (6-9 percent). The water charges command 5-6 percent of the total cost in case of marginal and small farmers whereas medium and large farmer expenditure is just 2-1 percent of the total cost on it.

Third, an analysis of certain other factors responsible for groundwater overuse in the region has been done. Cropping pattern assessment shows that majority of the respondents in all the villages stated that their cropping pattern has changed in last ten years and they currently follow only wheat-sugarcane cropping system. Earlier they used to grow vegetables, maize etc. but as it was not yielding higher returns so they stopped growing those crops. A major problem witnessed by farmers in production of wheat and sugarcane is high cost of irrigation. As both wheat and sugarcane are water intensive crops, extensive irrigation is required which is now solely dependent on groundwater. Though, majority of the farmers have installed submersible pumpsets on their farms, few still purchase it. Water charges in Gurana and Vazidpur ranges from Rs.40-50 per hour in this which is relatively less than Pura Mahadev and Mawi Kalan. Considering the credit availability, it is found that credit facility is majorly availed by medium and large farmers with 85 percent and 100 percent respectively taking loans for agricultural purposes. This clearly indicates that still credit penetration is low among marginal and small farmers.

Fourth, in order to see the factors affecting agriculture output, multiple regression model has been used. The results of the model depict that total output would increase 0.35 units if the farm lies in Mawi Kalan (high groundwater stressed, socially economically backward village) while it would rise by 0.44 percent if it is in Gurana region and with 0.41 percent in case of Pura Mahadev. Such outcomes portray that Gurana village is more productive than Mawi Kalan as they are in better position-socially, economically and hydrogeologically. Considering land size group, the regression results show that output in marginal farm category would reduce 1.32 percent and in small category it will dip down by 0.75 percent. The total production is estimated to increase by 0.57 percent if it's a large farm, suggesting large farms are productive within the sampled region. As far as association of household income with agricultural production is concerned, the results depict that households with less income are able to produce less. The influence of caste and religion on total production is also evident. Within the sampled region OBC category households are in better position socially and economically, therefore when a household belongs to this category agriculture output is expected to rise by 0.37 units. Further, the regression result shows that farmers belonging to Hindu religion category are able to produce more. The agricultural output is expected to rise by 0.62 units if farmer is a Hindu. Considering education, the regression estimates depict that if the farmer is literate then production would increase by 0.13 units.

Chapter *sixth* titled "**Groundwater: The Scenario and Perception in the Surveyed Area**" analyse the perception of farmer households about groundwater availability, accessibility, causes of water decline and response to depletion threats. It also assessed groundwater stress levels in different sampled villages and across land size groups.

First, considering the inter-village groundwater depth levels, data revealed that groundwater level is relatively higher in Gurana and Vazidpur wherein the usual depth is 70 and 90 ft respectively, while it is lower in Pura Mahadev and Mawi Kalan where the groundwater is available at a depth of 120ft and 130 ft. respectively. The supreme reason for water decline is inadequate canal infrastructure followed by access to groundwater abstraction technology and easy and flexible property of groundwater to be the key drivers of increased groundwater depth. Majority of the farmers in all villages depend upon pumpsets for irrigation. Inter- village frequency distribution shows that ownership of pumpsets is relatively lower in Gurana and Vazidpur than in Pura Mahadev and Mawi Kalan. This scenario could be seen from two sides; a) higher percentage of pumpsets owners has promoted groundwater scarcity in Pura Mahadev and Mawi Kalan; b) as the groundwater level is lower in these villages so the viable option that the farmers have is to install a pumpset on farm. Large and medium category a higher percentage of famers have submersible and few lack it while in marginal and small category, 25.08 percent in total could not own it. This throws light on the fact that marginal and small farmers lag behind in accessing groundwater through pumpsets. As far as awareness about energy efficient pumps is considered, 18.67 percent in the sampled villages were aware about the availability of energy saving pumps while 81.33 percent had no idea.

Second, the study deciphered the linkage between groundwater accessibility and land inequities. Land rights are the major reason behind their water insecurity while 12.67 percent see economic backwardness and 10 percent consider caste to be the primary factor. As land and water rights are linked, land distributional inequities pave way for water stress especially among small and marginal farmers.

Third, conceiving knowledge about the behavioural pattern of the farmers towards groundwater conservation it is seen that they literally compete with each other to obtain easy and larger share of groundwater. Out of the total 300 farmers, 48. 33 percent stated that they will deeper if their neighbouring farmer drills deeper or installs a more powerful pumpset. This problem can be basically identified with a prisoner's dilemma because the presence of firms playing their dominant strategy which maximizes their own profit (disregarding competitors' profits) leads to severe depletion of the resource, and consequently to low profits for all. Deeper analysis shows that marginal farmers belonging to Pura Mahadev and Mawi Kalan showcase far more competitive behaviour.

Fourth, in order to ascertain the perceived groundwater stress levels across different villages and land-size groups, a groundwater stress index has been formulated. Its results show that groundwater stress is highest in Mawi Kalan followed by Pura Mahadev, Vazidpur and Gurana. Land-size group wise the results depict that the heat of groundwater depletion is least felt by large farmers, while all other categories suffer.

Fifth, the study further estimated the health impact of groundwater degradation across different sampled villages it is found that the cases of water related illness is highest in Pura Mahadev (69) followed by Mawi Kalan (65), Vazidpur (37) and Gurana (32). Results of Logistic model show that the likelihood of experiencing water related infections is higher in families which are socio-economically backward and live in village where water levels are low. The chances proportion affirm that the odds of having a patient with water related illnesses is higher if the family units lives in land area where water table is beneath 100 ft. Thinking about the impact of education on occurrence of illness, the discoveries demonstrate that if the head of the household is educated, at there are less chances of a family member experiencing such infections as the general dimension of mindfulness in the family would be high. To the extent social category is concerned, the odds ratio indicates that the likelihood of family units to have a patient with water related illness is higher in different classes however not in OBC classification. Considering the effect of income level on occurrence of illness, it is seen that family units having a place with the lower 60 percent income group have higher chances to experience the ill effects of water related ailments. Family size has additionally been considered as a determinant of sickness so the calculated outcomes demonstrate that families with in excess of five individuals have higher odds of having people who experience the ill effects of water related ailment.

Chapter *seventh* entitled "**Willingness to Pay for Managing Groundwater by Farmer Households"** presents an outline of contingent valuation approach, estimates the Willingness to Pay (WTP) of farmer households for managing groundwater resources in the region and also encapsulates its determinants.

First, data analysis show that majority of the sampled population is willing to pay for groundwater management but a higher percent of people agreed in villages with high groundwater stress i.e. Pura Mahadev and Mawi Kalan. As groundwater problem is more precarious, so to solve the current crisis in these villages a higher proportion of people are willing to pay Rs.100 or above while it is not so in Gurana and Vazidpur.

Second, coming to the answers behind unwillingness to pay, data tells that majority of the respondents in all the villages believed that managing groundwater resources is the responsibility of government so they will not pay for it and few also stated that until unless the present needs are met there is no need to worry about the future.

Third, considering the determinants of willingness to pay (WTP), the results of logistic regression reveal that with reference to social factors, age and caste of the respondent have significant relationship with willingness to pay while the education level's association is statistically insignificant. The odd ratio shows that the probability of farmer household to pay a higher amount for managing groundwater problem is less if respondent belong to caste other than OBC. Considering age of the respondent, the results depict that WTP of the young person is less than an old/matured person. As far as effect of education is concerned, the regression output depicts a negative and statically insignificant relationship. Taking into account the economic factors, land size, income level and value of agriculture output all show a statistically significant association with WTP. Increase in farm size leads to rise in willingness to pay. Income of the household also has a positive relationship with WTP. Considering hydrogeological factors viz. location of the village and groundwater stress level, the results show that both these variables are positively and statistically related. If the household belong to Mawi Kalan village as there are more chances that it will pay above Rs. 50 per month to solve the groundwater problem. The groundwater stress level also highly affects the WTP. The odd ratio reveals that if the household's groundwater stress level is high then there are higher chances to pay more.

8.2. Conclusions

Groundwater depletion and degradation is a serious matter of concern as it reduces food production, productivity, increases cost of cultivation, discourages farmers to invest more, leads to migration, social inequities and fall in income levels. Different global and national agencies have evaluated the degree and dimensions of groundwater scarcity/ stress in different parts of the world and have consistently conceded to the gravity of the situation and stated that management of the available resource is the only option.

Groundwater mismanagement in Indian agriculture sector is to great extent interplay of institutional, social, economic, political and ecological factors. Poor state of farmers, lack of canal infrastructure and ineffective rules/regulations could be very important reasons for groundwater stress in districts of Uttar Pradesh. The agrarian, socio-economic and hydrogeological analysis of farmer households in our study area corroborates that land size differences, education level, caste, income, water depth, awareness about environment, behavioural patterns all are significant factors affecting groundwater use and management. The study has been carried out in one of the most critical areas with reference to groundwater stress in Uttar Pradesh, therefore, the results help in highlighting that though groundwater scarcity is not acute in all the regions of Uttar Pradesh but districts like Baghpat are highly affected. The people are suffering to a large extent and there are multiple factors behind groundwater overexploitation. The estimated results clearly show the inter-village and inter-land size differentials that exist in agriculture production, productivity, cost of cultivation, income from agriculture and WTP within the dynamics of groundwater resources. The study findings suggest that the most vulnerable is the ultimate sufferer and is the one who is ready to spend a higher amount to come out of the problem.

8.3. Policy Recommendations

- Groundwater is a very complicated resource. Any individual tapping into an aquifer is tapping into a common resource pool which others can also use. However, large farmers have higher potential to withdraw groundwater and the resource poor farmers are dependent on groundwater markets wherein they have to pay discretionary prices. Though, it is not possible to meet the needs of the large farmer population in India only through surface water so states can facilitate groundwater trade, and reduce costs for water buyers, by introducing institutional mechanisms to curb unsustainable use and fixing a ceiling price as per the hydrogeological and socio-economic setting.

- A persistent problem in India's canal irrigation system is negligence by officials and lack of proper maintenance of canals. The investment in improvising and innovating the canal infrastructure is necessary so as to distribute the burden between surface and groundwater resources. Further, as groundwater abstraction is easy and flexible the water usage pattern is far more unsustainable.
- Separate electricity feeder system for agriculturists in Uttar Pradesh is an effective mechanism to curb over-extraction of groundwater. It has been effectively implemented in few states viz. Gujarat and Punjab etc. but lacks enactment in other states. Initiation of this policy would aid in gaining accountability in the subsidy provided to agricultural consumers. Further, it will help in providing continuous three phase supply to rural consumers, improvise load management, reduce line losses and enhance the energy efficiency of agricultural equipments such as water pumpsets.
- Precision agriculture is a kind of farm management approach in which taking into account the basic nature of the physical conditions of the area, the farm is managed with accuracy. The farmer has to take several decisions during the crop cycle which involve technical knowledge and expertise. Precision agriculture market includes technologies viz. guidance system, remote sensors and variable rate technologies. Adoption of precision agriculture tools would enable farmer to undertake informed decisions as well as indulge in sustainable farm practices.
- Farmers are aware about rising water stress but are not worrisome about it in the regions where groundwater is available. It is necessitated that they are educated about the issues emerging out of groundwater over-misuse.
- As groundwater is a complex resource and establishment of rights is a tedious task, government regulation and privatisation are not feasible solutions. Community management can prove to be a powerful tool in conservation of this valuable resource. There are several success stories of community management of water resources which can be replicated or modified as per the local setting and the participatory members can be provided financial incentive by the government.

8.4. Limitations of the Study

Inspite of sincere efforts in conducting this study, there are few limitations which cannot be ignored:

- In order to decipher the factors which influence groundwater use and management particularly in agriculture mainly secondary data has been used. The availability and accuracy of such data is beyond the researcher's scope.
- The scope of the study is broader but due to resource constraints the sample size is limited to 300 households.
- The data analysis in this study includes simple regression, multiple and logistic regression models which have their own limitations.
- There are several environmental valuation techniques while this study utilised Willingness to pay which has limitations of its own**.**

8.5. Further Scope of the Study

- The study carried out and presented in the thesis can serve as model for future studies to understand the varied socio-economic and contextual aspects related to groundwater.
- As groundwater is a major source of water in all sectors of the economy future studies on similar background can be conducted with respect to industrial or other sectors.
- Household survey was limited to specific areas of Baghpat district, however, the problem of groundwater stress is widespread. Therefore, a wider survey with the aim of capturing extent and dynamics of groundwater depletion can be conducted.
- In order to make an assessment of behavioural patterns on environmental problems application of certain advanced econometric tools and techniques can be made.
- Extensive studies can be undertaken on groundwater as very limited amount of research work in this field has been done by social scientists.

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Appendices

Appendices

Table 3.9.1A: State wise Percent of Number of Operational Landholdings by Farm size Categories during 2000-2015

NUMBER																
STATES	Marg[1] 2000-01	Marg 2005-06	Marg 2010-11	Marg 2015-16	Small 2000-01	Small 2005-06	Small 2010-11	Small 2015-16	Med 2000-01	Med 2005-06	Med 2010-11	Med 2015-16	Large 2000-01	Large 2005-06	Large 2010-11	Large 2015-16
A & N ISLANDS	32.21	41.61	39.19	41.67	23.67	18.27	20.46	25.00	43.75	39.77	40.06	33.33	0.37	0.35	0.27	0.00
ANDHRA PRADESH	60.90	61.59	63.94	69.26	21.84	21.91	22.15	19.31	16.69	16.04	13.27	11.25	0.57	0.47	0.27	0.18
ARUNACHAL PRADESH	14.04	20.33	19.63	23.89	18.78	23.11	17.69	21.24	61.85	52.68	56.70	48.67	5.33	3.88	5.97	6.19
ASSAM	62.65	63.74	67.31	68.15	20.69	21.51	18.25	18.06	16.48	14.57	14.27	13.64	0.18	0.18	0.15	0.15
CHANDIGARH	57.99	68.75	63.45	NA	19.84	17.59	18.63	NA	21.29	13.30	17.50	NA	0.88	0.36	0.42	NA
CHATTISGARH	53.66	55.44	58.26	60.67	22.00	21.95	22.18	21.92	23.14	21.62	18.81	16.82	1.20	0.99	0.74	0.58
DELHI	56.23	55.50	55.17	55.00	21.29	22.48	22.04	25.00	21.52	21.24	22.06	20.00	0.97	0.77	0.73	0.00
GOA	81.64	80.92	76.78	80.36	10.29	10.96	12.58	10.71	7.26	7.34	9.89	8.93	0.81	0.78	0.75	0.00
GUJARAT	30.61	34.01	37.16	37.93	29.64	28.86	29.25	30.38	38.21	35.68	32.58	30.94	1.54	1.45	1.00	0.75
HARYANA	46.08	47.67	48.11	49.32	19.25	19.42	19.47	19.29	31.41	29.87	29.58	28.87	3.26	3.04	2.83	2.52
HIMACHAL PRADESH	67.29	68.21	69.78	71.49	19.06	18.82	18.17	17.37	13.21	12.60	11.71	10.84	0.43	0.38	0.34	0.30
JAMMU & KASHMIR	81.42	81.50	83.25	83.77	12.39	12.28	11.53	11.29	6.16	6.17	5.18	4.87	0.04	0.05	0.04	0.07
KARNATAKA	45.94	48.23	49.14	54.90	26.97	26.56	27.30	25.50	25.83	24.17	22.70	18.95	1.26	1.05	0.86	0.65
KERALA	95.17	95.63	96.32	96.70	3.41	3.11	2.64	2.39	1.38	1.22	1.01	0.88	0.04	0.04	0.03	0.03
LAKSHADWEEP	95.52	95.79	95.81	100.00	3.16	2.61	2.60	0.00	1.26	1.52	1.52	0.00	0.06	0.08	0.08	0.00
MADHYA PRADESH	38.56	40.45	43.86	48.33	26.51	27.16	27.60	27.24	32.67	30.79	27.55	23.80	2.26	1.60	1.00	0.63
MANIPUR	50.50	50.85	50.95	50.99	32.63	32.44	32.43	32.45	16.84	16.69	16.59	16.56	0.03	0.03	0.03	0.00
MEGHALAYA	NA	55.34	49.01	53.02	NA	27.23	27.56	25.86	NA	17.31	23.31	21.12	NA	0.12	0.11	0.00
MIZORAM	44.62	48.34	54.65	50.56	37.04	34.61	32.38	30.34	18.27	16.96	12.68	19.10	0.08	0.08	0.29	0.00
NAGALAND	3.34	7.31	3.63	4.06	6.18	7.97	11.40	14.72	66.64	66.72	70.86	69.54	23.84	18.01	14.11	11.68
ODISHA	16.29	59.60	72.17	74.74	79.04	26.55	19.68	18.23	4.58	13.59	8.03	6.95	0.09	0.27	0.12	0.08
PUDUCHERRY	NA	78.95	85.71	84.85	NA	12.15	8.36	9.09	NA	8.55	5.71	6.06	NA	0.35	0.21	0.00
PUNJAB	12.31	13.42	15.62	14.10	17.35	18.22	18.57	18.96	63.08	61.29	59.19	61.63	7.25	7.06	6.62	5.31

[1] Marg denotes marginal farm size

RAJASTHAN	31.78	33.51	36.46	40.12	20.79	21.36	21.94	21.91	39.53	38.21	35.74	33.28	7.91	6.93	5.86	4.69
SIKKIM	54.50	54.25	54.02	65.67	23.05	22.53	22.61	19.40	21.35	22.06	22.33	14.93	1.10	1.16	1.04	0.00
TAMIL NADU	73.92	76.01	0.00	78.41	16.14	15.06	0.00	14.10	9.65	8.69	NA	7.31	0.30	0.24	0.00	0.19
TRIPURA	NA	86.77	86.27	87.96	NA	9.63	9.52	8.38	NA	3.58	4.20	3.66	NA	0.03	0.01	0.00
UTTAR PRADESH	76.88	77.96	79.45	80.18	14.25	13.82	13.01	12.63	8.72	8.10	7.43	7.10	0.15	0.12	0.11	0.10
UTTARAKHAND	70.54	NA	NA	74.80	17.78	NA	NA	16.91	11.52	NA	NA	8.17	0.16	NA	NA	0.11
WEST BENGAL	80.44	80.11	81.28	82.80	14.86	14.69	14.06	13.40	4.68	5.18	4.63	3.78	0.01	0.02	0.02	0.01
ALL INDIA	56.65	63.88	64.78	68.52	26.50	18.63	18.61	17.69	15.77	16.47	15.72	13.22	1.07	1.02	0.89	0.57

Source: Various Rounds of Agriculture Census, Ministry of Agriculture, Government of India

Table 3.9.2A: State wise Percent of Area of Operational Landholdings according to different Farm size categories during 2000-2015

	AREA															
	Marg[2] 2000-01	Marg 2005-06	Marg 2010-11	Marg 2015-16	Small 2000-01	Small 2005-06	Small 2010-11	Small 2015-16	Med 2000-01	Med 2005-06	Med 2010-11	Med 2015-16	Large 2000-01	Large 2005-06	Large 2010-11	Large 2015-16
A & N ISLANDS	6.31	9.80	9.25	9.52	16.28	14.65	15.85	19.05	68.76	68.63	69.34	66.67	8.66	6.92	5.57	4.76
ANDHRA PRADESH	26.74	22.68	26.08	29.19	30.70	25.74	28.82	29.16	33.26	45.50	41.23	38.21	9.30	6.05	3.87	3.45
ARUNACHAL PRADESH	1.90	3.14	3.09	3.69	6.73	9.11	6.75	8.18	68.07	70.25	64.81	60.69	23.30	17.51	25.34	27.44
ASSAM	21.29	24.93	25.83	26.38	23.46	23.56	22.91	23.39	46.79	41.71	41.86	40.86	8.46	9.80	9.40	9.38
CHANDIGARH	15.83	25.61	22.54	NA	19.51	22.51	20.59	NA	57.36	47.72	53.20	NA	7.30	4.16	3.58	NA
CHATTISGARH	14.86	16.12	18.74	20.77	19.50	20.69	23.20	24.77	53.33	52.27	49.18	46.96	12.31	10.92	8.88	7.50
DELHI	17.59	15.82	16.20	17.24	8.76	20.75	20.14	27.59	62.68	55.85	55.99	48.28	10.97	7.58	7.66	6.90
GOA	31.36	20.45	31.58	28.89	15.41	11.83	19.77	15.56	30.39	22.29	32.75	37.78	22.83	45.44	15.90	17.78
GUJARAT	7.01	7.71	8.94	10.75	18.57	19.08	20.96	23.43	63.23	62.17	59.80	59.90	11.18	11.03	10.30	5.91
HARYANA	8.92	9.66	9.89	10.86	11.88	12.51	12.69	12.74	56.09	55.44	54.86	54.57	23.11	22.40	22.56	21.83
HIMACHAL PRADESH	25.72	26.67	28.62	30.22	24.99	25.27	25.55	25.66	42.83	41.86	40.53	39.13	6.45	6.20	5.29	4.98
JAMMU & KASHMIR	44.59	44.06	NA	47.15	25.95	25.73	NA	26.25	28.20	28.94	NA	25.30	1.26	1.27	NA	1.31

[2] Marg denotes marginal farm size

KARNATAKA	12.13	13.33	15.22	17.61	22.28	23.22	24.83	26.32	54.81	53.88	51.78	48.77	10.78	9.56	8.17	7.29
KERALA	56.23	57.61	58.62	61.36	19.10	18.32	18.69	17.35	17.54	16.55	14.77	14.48	7.13	7.52	7.92	6.81
LAKSHADWEEP	65.70	62.61	62.20	100.0	14.67	13.13	13.27	0.00	14.85	17.38	17.56	0.00	4.78	6.87	6.94	0.00
MADHYA PRADESH	8.54	9.93	12.10	15.14	17.28	19.24	21.89	24.48	58.45	58.71	57.18	54.43	15.73	12.12	8.84	5.95
MANIPUR	23.33	23.24	23.36	23.39	36.46	36.51	36.47	36.84	39.94	39.99	39.91	39.77	0.26	0.26	0.26	0.00
MEGHALAYA	NA	22.72	16.08	18.67	NA	30.50	26.75	26.67	NA	44.37	55.81	53.33	NA	2.41	1.37	1.33
MIZORAM	23.06	24.37	28.79	23.89	38.40	37.14	36.00	30.97	37.72	35.51	31.41	41.59	0.82	2.99	3.80	3.54
NAGALAND	0.24	0.49	0.31	0.40	1.01	1.35	2.15	3.61	46.93	47.57	56.38	60.42	51.83	50.59	41.17	35.57
ODISHA	22.71	26.68	39.61	44.53	30.45	31.60	30.87	30.40	42.50	38.06	26.80	23.21	4.33	3.65	2.72	1.86
PUDUCERRY	NA	30.09	45.11	38.10	NA	22.11	18.66	23.81	NA	39.62	30.73	33.33	NA	8.18	5.50	4.76
PUNJAB	1.93	2.10	2.55	2.35	6.02	6.52	6.78	7.34	64.82	64.46	64.74	68.63	27.24	26.92	25.93	21.68
RAJASTHAN	4.21	4.85	5.86	7.10	8.20	9.05	10.23	11.44	48.12	49.50	50.59	52.16	39.46	36.59	33.33	29.29
SIKKIM	14.77	13.84	13.88	23.68	20.61	19.16	19.12	23.68	50.10	52.57	55.46	44.74	14.52	14.44	11.53	7.89
TAMIL NADU	30.97	33.51	NA	36.33	24.56	25.22	NA	26.05	37.95	35.54	NA	32.31	6.53	5.73	NA	5.31
TRIPURA	NA	49.71	49.03	52.84	NA	26.59	26.60	24.82	NA	20.06	23.94	21.99	NA	3.64	0.43	0.35
UTTAR PRADESH	36.97	38.93	40.69	41.82	24.28	24.24	24.08	23.92	36.06	34.46	33.07	32.29	2.69	2.37	2.16	1.97
WEST BENGAL	49.74	48.05	50.40	53.39	28.97	28.48	28.06	28.31	17.35	19.43	17.58	14.29	3.95	4.04	3.96	4.01
ALL- INDIA	18.61	19.60	21.13	24.16	19.77	20.14	21.22	23.19	46.46	46.84	46.07	43.61	15.14	13.42	12.30	9.04

Various Rounds of Agriculture Census, Ministry of Agriculture, Government of India.

Appendices

Table 3.10.1A: State wise ownership of Groundwater schemes according to landholding size during 2000-2014 (in percent)

	NUMBER OF GROUNDWATER SCHEMES OWNED											
	Marg[3]	Marg	Marg	Small	Small	Small	Med	Med	Med	Large	Large	Large
STATES	2000-01	2006-07	2013-14	2000-01	2006-07	2013-14	2000-01	2006-07	2010-11	2000-01	2006-07	2013-14
Andhra Pradesh	35.94	40.81	40.28	36.91	35.21	35.22	25.79	23.46	24.02	1.37	0.52	0.47
Arunachal Pradesh	50.00	NA	NA	0.00	0.00	NA	50.00	NA	NA	0.00	0.00	NA
Assam	37.15	7.85	4.92	40.89	32.58	30.94	20.53	59.36	63.84	1.43	0.21	0.28
Bihar	38.71	17.79	NA	38.20	30.09	NA	20.73	47.72	NA	2.37	4.41	NA
Chattisgarh	21.40	20.05	24.16	28.10	28.10	32.83	45.30	46.14	39.99	5.21	5.70	3.00
Goa	75.96	69.13	55.23	13.05	14.62	9.85	9.71	14.31	34.02	1.29	1.94	0.88
Gujarat	29.42	29.14	36.73	33.27	34.57	32.94	35.76	30.70	27.10	1.54	5.59	3.21
Haryana	5.25	1.29	0.15	13.05	13.90	19.19	37.20	84.81	77.15	44.50	0.00	3.50
Himachal Pradesh	24.08	26.05	36.11	21.38	29.08	32.08	26.63	41.63	29.47	27.91	3.24	2.32
Jammu & Kashmir	38.56	10.77	66.85	33.87	54.56	23.51	21.38	33.47	9.59	6.19	1.20	0.03
Karnataka	43.57	30.17	37.47	36.53	35.79	33.16	19.64	32.49	27.85	0.26	1.55	1.50
Kerala	89.85	87.81	88.01	8.88	8.24	8.79	1.21	3.29	2.69	0.07	0.66	0.50
Madhya Pradesh	13.75	14.11	16.36	28.80	28.38	31.35	52.14	54.26	49.61	5.32	3.24	2.66
Nagaland	40.77	0.00	0.00	37.98	15.49	0.00	19.51	84.51	100.00	1.74	0.00	0.00
Odisha	37.28	29.73	34.69	39.18	34.72	34.06	21.80	34.06	30.23	1.74	1.49	1.00
Punjab	5.31	3.93	4.10	16.40	13.40	14.29	70.44	72.89	73.56	7.86	9.78	8.03
Rajasthan	9.06	9.18	8.63	23.09	20.16	19.22	61.01	63.68	61.29	6.84	6.98	10.80
Tamil Nadu	51.20	52.17	NA	29.84	28.15	NA	17.99	17.05	NA	0.98	2.64	NA

[3] Marg denotes marginal farm size

Table 6.3A: Land Size Group wise Ownership of Pumpset

Land Size	No	Yes	Total
Marginal	17 13.49* 60.71**	109 86.51* 53.43**	126 100* 54.31**
Small	8 12.31* 28.57**	57 87.69* 27.94**	65 100* 28.02**
Medium	3 8.11* 10.71**	34 91.89* 16.67**	37 100* 15.95**
Large	0 0* 0**	4 100* 1.96**	4 100* 1.72**
Total	28 12.07* 100**	204 87.93* 100**	232 100* 100**

Source- Estimated from Field Survey Data
Note: *row percentage, **column percentage; Pearson chi2(3) = 1.33 Pr = 0.72

Table 6.4A: Land Size Group wise Distribution of Pumpsets according to Horsepower

Land Size	Upto 5 HP	6-10 HP	Above 10 HP	Total
Marginal	5 4.59* 62.5**	6 5.5* 60**	98 89.91* 53.26**	109 100* 53.43**
Small	3 5.26* 37.5**	3 5.26* 30**	51 89.47* 27.41**	57 100* 27.94**
Medium	0 0* 0**	1 2.94* 10**	33 97.06* 17.93**	34 100* 16.67**
Large	0 0* 0**	0 0* 0**	4 100* 1.96**	4 100* 1.96**
Total	8 3.92* 100**	10 4.9* 100**	186 91.18* 100**	204 100* 100**

Source- Estimated from Field Survey Data
Note: *row percentage, **column percentage; Pearson chi2(12) = 61.48 Pr = 0.00

Table 6.8A: Village wise Perception about existence of Informal Arrangement for Groundwater Accessibility

Village	Yes	No	Total
Gurana	71 94.67* 24.74**	4 5.33* 30.77**	75 100* 25**
Vazidpur	71 94.67* 24.74**	4 5.33* 30.77**	75 100* 25**
Pura-Mahadev	73 97.33* 25.44**	2 2.67* 15.38**	75 100* 25**
Mawi Kalan	72 96* 25.09**	3 4* 23.08**	75 100* 25**
Total	287 95.67* 100**	13 4.33* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note: *row percentage, **column percentage; Pearson chi2(3) = 0.88 Pr = 0.82

Table 6.9A: Village wise Respondent's view on Equity between Small scale and large scale farmers

Village	Yes	No	Total
Gurana	12 16* 46.15**	63 84* 22.99**	75 100* 25**
Vazidpur	14 18.67* 53.85**	61 81.33* 22.26**	75 100* 25**
Pura-Mahadev	0 0* 0**	75 100* 27.37**	75 100* 25**
Mawi Kalan	0 0* 0**	75 100* 27.37**	75 100* 25**
Total	26 8.67* 100**	274 91.33* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note: *row percentage, **column percentage; Pearson chi2(3) = 28.80 Pr = 0.00

Table 6.10A: Village wise Respondent's view on Land Integration to improve water and irrigation efficiency

Village	Yes	No	Total
Gurana	73 97.33* 26.16**	2 2.67* 9.52**	75 100* 25**
Vazidpur	70 93.33* 25.09**	5 6.67* 23.81**	75 100* 25**
Pura-Mahadev	65 86.67* 23.3**	10 13.33* 47.62**	75 100* 25**
Mawi Kalan	71 94.67* 25.45**	4 5.33* 19.05**	75 100* 25**
Total	279 93* 100**	21 7* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note: *row percentage, **column percentage; Pearson chi2(3) = 7.11 Pr = 0.06

Table 6.11A: Village wise Respondent's view on Affect of Land ownership status on Social Equity in terms of Groundwater Accessibility

Village	High	Moderate	Low	Total
Gurana	34 45.33* 23.94**	36 48* 27.48**	5 6.67* 18.52**	75 100* 25**
Vazidpur	43 57.33* 30.28**	28 37.33* 21.37**	4 5.33* 14.81**	75 100* 25**
Pura-Mahadev	26 34.67* 18.31**	36 48* 27.48**	13 17.33* 48.15**	75 100* 25**
Mawi Kalan	39 52* 27.46**	31 41.33* 23.66**	5 6.67* 18.52**	75 100* 25**
Total	142 47.33* 100**	131 43.67* 100**	27 9* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note: *row percentage, **column percentage; Pearson chi2 = 13.77 Pr = 0.03

Table 6.12A: Village wise Respondent's view on Main Obstacle behind Water Insecurity

Village	Land right	Caste	Gender	Govt. Support	Economic	Others	Total
Gurana	43 57.33* 22.16**	9 12* 30**	0 0* 0**	8 10.67* 24.24**	15 20* 39.47**	0 0* 0*	75 100* 25**
Vazidpur	49 65.33* 25.26**	4 5.33* 13.33**	1 1.33* 33.33**	11 14.67* 33.33**	10 13.33* 26.32**	0 0* 0**	75 100* 25**
Pura-Mahadev	56 74.67* 28.87**	6 8* 20**	2 2.67* 66.67**	5 6.67* 15.15**	5 6.67* 13.16**	1 1.33* 50**	75 100* 25**
Mawi Kalan	46 61.33* 23.71**	11 14.67* 36.67**	0 0* 0**	9 12* 27.27**	8 10.67* 21.05**	1 1.33* 50**	75 100* 25**
Total	194 64.67* 100**	30 10* 100**	3 1* 100**	33 11* 100**	38 12.67* 100**	2 0.67* 100**	300 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage, **column percentage; Pearson chi2(15) = 19.30 Pr = 0.20

Table 7.1A: Land Size group wise Willingness to Pay-Yes/No

Land Size	Yes	No	Total
Marginal	144 81.36* 60.76**	33 18.64* 52.38**	177 100* 59**
Small	53 67.09* 22.36**	26 32.91* 41.27**	79 100* 26.33**
Medium	37 92.5* 15.61**	3 7.5* 4.76**	40 100* 13.33**
Large	3 75* 1.27**	1 25* 1.59**	4 100* 1.33**
Total	237 79* 100**	63 21* 100**	300 100* 100**

Source- Estimated from Field Survey Data
Note: *row percentage, **column percentage; Pearson chi2(3) = 11.78 Pr = 0.00

Table 7.2A : Land Size group wise Monthly Amount that Respondents like to pay

Land Size	Rs.25	Rs.50	Rs.75	Rs.100	Rs.125 & above	Total
Marginal	45 31.25* 76.27**	20 13.89* 62.5**	30 20.83* 63.83**	24 16.67* 47.06**	25 17.36* 52.08**	144 100* 60.76**
Small	12 22.64* 20.34**	6 11.32* 18.75**	8 15.09* 17.02**	13 24.53* 25.49**	14 26.42* 29.17**	53 100* 22.36**
Medium	2 5.41* 3.39**	6 16.22* 18.75**	9 24.32* 19.15**	12 32.43* 23.53**	8 21.62* 16.67**	37 100* 15.61**
Large	0 0* 0**	0 0* 0**	0 0* 0**	2 66.67* 3.92**	1 33.33* 2.08**	3 100* 1.27**
Total	59 24.89* 100**	32 13.5* 100**	47 19.83* 100**	51 21.52* 100**	48 20.25* 100**	237 100* 100**

Source- Estimated from Field Survey Data
Note: *row percentage, **column percentage; Pearson chi2(15) = 32.62 Pr = 0.00

Table 7.3A: Land Size group wise Primary Reason for Willingness to Pay

Land Size	For solving Crisis	Future Shortages	Current Exp.	Water is a right	Good Cause	Coerce Coop.	Total
Marginal	68 47.22* 61.26**	21 14.58* 70**	28 19.44* 65.12**	8 5.56* 61.54**	5 3.47* 62.5**	14 9.72* 43.75**	144 100* 60.76**
Small	28 52.83* 25.23**	6 11.32* 20**	7 13.21* 16.28**	3 5.66* 23.08**	3 5.66* 37.5**	6 11.32* 18.75**	53 100 22.36**
Medium	14 37.84* 12.61**	3 8.11* 10**	8 21.62* 18.6**	2 5.41* 15.38**	0 0* 0*	10 27.03* 31.25**	37 100* 15.61**
Large	1 33.33* 0.9**	0 0* 0**	0 0* 0**	0 0* 0**	0 0* 0**	2 66.67* 6.25**	3 100* 1.27**
Total	111 46.84* 100**	30 12.66* 100**	43 18.14* 100**	13 5.49* 100**	8 3.38* 100**	32 13.5* 100**	237 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage, **column percentage; Pearson chi2(15) = 19.63 Pr = 0.18

Table 7.4A: Land Size wise Primary Reason for Unwillingness to Pay

Land Size	No Severe Crisis	No worry About Future	Exp.too high	Insuff. Income	Govt ShouldPay	Other	Total
Marginal	1 3.03* 100**	6 18.18* 54.55**	4 12.12* 100**	11 33.33* 78.57**	10 30.3* 34.48**	1 3.03* 25**	33 100* 52.38**
Small	0 0* 0**	5 19.23* 45.45**	0 0* 0**	2 7.69* 14.29**	16 61.54* 55.17**	3 11.54* 75**	26 100* 41.27**
Medium	0 0* 0**	0 0* 0**	0 0* 0**	0 0* 0**	3 100* 10.34**	0 0* 0**	3 100* 4.76**
Large	0 0* 0**	0 0* 0**	0 0* 0**	1 100* 7.14**	0 0* 0**	0 0* 0**	1 100* 1.59**
Total	1 1.59* 100**	11 17.46* 100**	4 6.35* 100**	14 22.22* 100**	29 46.03* 100**	4 6.35* 100**	63 100* 100**

Source- Estimated from Field Survey Data

Note: *row percentage, **column percentage; Pearson chi2(15) = 20.41 Pr = 0.15

Annexure-I

Groundwater Sustainability: A Common Pool Resource Approach towards its Management

Research Study

BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY

By
Pragya Sharma
Babasaheb Bhimrao Ambedkar University, Lucknow
[A Central University]

Block 1: General Background Information (सामान्य पृष्ठभूमि जानकारी)

1.1 State (राज्य) | 1.2 District (जिला)

1.3 Name of Block (खंड) | 1.4 Name of Village (गांव)

1.5 Name of Locality (इलाका) | 1.6 Household Code (गृह कोड)

1.7 Name of Respondent (प्रतिवादी का नाम)..

1.8 Full Address of Respondent
(आवासीय पता) ....

....

1.9 Gender of respondent (Male-1; Female-2, Transgender-3)
प्रतिवादी का लिंग (पुर्लिंग-1; स्त्रीलिंग-2; ट्रांसजेंडर-3)

1.10 Are you the Head of the household? (Yes-1, No-2)
क्या आप परिवार के मुखिया हैं (हाँ-1; ना-2)

1.11 Age of respondent (in completed years)
प्रतिवादी की आयु (वर्षों में)

1.12 Religion (Hindu-1; Muslim-2; Christian-3; Sikh-4; Others-5)
प्रतिवादी का धर्म (हिन्दू-1; मुस्लिम-2; ईसाई -3; सिख-4; अन्य-5)

1.13 Caste category (SC-1; ST-2; OBC-3; General-4; Others-5)
प्रतिवादी की जाति श्रेणी (अनुसूचित जाति-1; अनुसूचित जनजाति-2; सामान्य-3; अन्य-4)

1.14 Education level (not literate-1, literate without formal schooling-2,
Literate below primary-3, Primary-4, middle-5, Secondary-6, higher secondary-7
Graduate-8, certificate/diploma (below graduate level)-9, postgraduate and above-10
निरक्षर -1; अनौपचारिक साक्षर -2;पूर्व प्राथमिक साक्षर -3;प्राथमिक -4; मिडिल -5;माध्यमिक-6; उच्च माध्यमिक-7; स्नातक-8; certificate/ डिप्लोमा-9 ; स्नातकोतर-10

1.15	No.of family members परिवार के सदस्यों की संख्या	

1.16	Dwelling unit code (owned –1, hired –2, no dwelling unit –3, others –4) रिहायशी इकाई (निजी सम्पति-1; किराये पर-3; बेघर-3; अन्य-4)	
1.17	Type of house structure (katcha-1, semi-pucca-2, pucca-3) मकान की संरचना (कच्चा-1; अर्ध पक्का-2; पक्का-3)	
1.18	Whether household possess any land? (yes - 1, no - 2) किसी प्रकार की भूमि है? (हाँ-1; ना-2)	
1.19	Type of land possessed (Homestead only-1; homestead and other land only-2; other land only-3) घर की भूमि-1; घर व अन्य भूमि-2; अन्य-3)	
1.20	Does the household possess any land outside the village (code)? गॉव के बाहर किसी भूमि के मालिक हैं?(हाँ-1; ना-2)	
1.21	Whether operated any land for agricultural activities during last 6 months? (yes-1, no-2) पिछले 6 महीने में किसी भूमि पे कृषि कार्य किया है? (हाँ-1; ना-2)	
1.22	land as on date of survey(ha 0.000) Owned-निजी	
	Leased in- पट्टे पर ली हुई भूमि	
	Leased out- पट्टे पर दी हुई भूमि	
	Total possessed (कुल)	
1.23	Principal Source of Income(Cultivation-1;Livestock2;Other agriculture activity-3, Other than Agriculture-4, please specify)आय का मुख्य स्रोत (खेती-1; पशुपालन-2; अन्य कृषि गतिविधियां-3; अन्य-4, स्पष्ट करें)	
1.24	Secondary Source of Income(Cultivation-1;Livestock2;Other agriculture activity-3, Other than Agriculture-4, please specify) आय का द्वितीयक स्रोत (खेती-1; पशुपालन-2; अन्य कृषि गतिविधियां-3; अन्य-4, स्पष्ट करें)	
1.25	Principal source of water for farming (Tubewell-1; Canal-2; openwells-3; ponds-4; Tanks-5; Handpump-6; Tap-7) सिंचाई का मुख्य स्त्रोत (नलकूप-1; नहर-2; खुले कुएं-3;तालाब-4; टैंक-5, हैंडपंप-6; नल-7)	
1.26	Secondary source of water for farming (Tubewell-1; Canal-2; openwells-3; ponds-4; Tanks-5, Handpump-6; Tap-7) सिंचाई का द्वितीयक स्रोत (नलकूप-1; नहर-2; खुले कुएं-3;तालाब-4; टैंक-5, हैंडपंप-6; नल-7)	
1.27	Principal source of water for domestic use (Tubewell-1; Canal-2; openwells-3; ponds-4; tanks-5; Handpump-6; Tap-7)घरेलु गतिविधियों के लिए पानी का मुख्य स्त्रोत(नलकूप-1; नहर-2; खुले कुएं-3;तालाब-4; टैंक-5; हैंडपंप-6; नल-7)	
1.28	Secondary source of water for domestic use (Tubewell-1; Canal-2; openwells-3; ponds-4; tanks-5; Handpump-6; Tap-7)घरेलु गतिविधियों के लिए पानी का द्वितीयक स्रोत (नलकूप-1; नहर-2; खुले कुएं-3;तालाब-4; टैंक-5; हैंडपंप-6; नल-7)	

	Person ID अनुक्रमांक	Name परिवार के सदस्यों के नाम	Relation to Head of the Household परिवार के मुखिया से संबंध	Age आयु	Gender (Male-1, Female-2, Transgendr-3) लिंग	Education शिक्षास्तर (code as in 1.14)	Activity Status*	Occupation (NCO code) कार्य	Income आय (Annual)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

* Self employment-1; Regular salaried-2; Non Agricultural Income-3; Agricultural labour-4; Unemployed-5; Domestic work-6; Domestic work and other side work-7, Student-8, Services-9, Others-10

स्व रोजगार -1; नियमित वेतनभोगी -2; गैर कृषि आय -3; कृषि श्रम -4; बेरोजगार -5; घरेलू काम -6; घरेलू काम और दूसरी तरफ काम -7, छात्र -8, सेवाएं -9, अन्य -10

Block 3: Cropping pattern (फसल पैटर्न)

	Crops फसल (code)	Area कुल क्षेत्र (acres)	Production Quantity उत्पादन मात्रा	Sale Quantity (q) बिक्री	Rate (r) मूल्य	Total Value कुल मूल्य	Total Sale (q*r) कुल बिक्री
RABI	Wheat गेहूं						
	Barley जौं						
	Gram चना						
	Masur मसूर						
	Mustard सरसों						
	Others अन्य						

Block 3(a) Season-Kharif

	Crops फसल (code)	Area कुल क्षेत्र (acres)	Production Quantity उत्पादन मात्रा	Sale Quantity (q) बिक्री	Rate (r) मूल्य	Total Value कुल मूल्य	Total Sale (q*r) कुल बिक्री
KHARIF	Rice चावल						
	Maize मक्का						
	Bajra मक्का						
	Soybean सोयाबीन						
	Cotton कपास						
	Sugarcane गन्ना						
	Pulses दाल						
	Others अन्य						

3.2 Have your cropping pattern changed over the years with rising water depletion?(Yes-1, No-2)
क्या पिछले कुछ वर्षों में आपका फसल पैटर्न पानी की कमी की वजह से परिवर्तिति हुआ हैं?
(हाँ-1; ना-2)

3.3 If yes, then, have you stopped growing a particular crop-1; grow less of a crop now-2; introduced new crop-3
अगर हाँ, तो क्या कोई फसल उगानी बंद कर दी हैं-1 कोई फसल अब कम उगते हैं-2, उसकी जगह पर अब कोई नयी फसल उगाने लगें हैं-3

3.4 What are the three primary reasons for this shift in cropping pattern?
(Higher returns-1, High productivity, Suitable for climate-3, Less effort-4, Peer influence-5, Needs less water-6, Needs less labour-7, High subsidy-8, Others-9)(Multiple preferences)
फसल पैटर्न में बदलाव के मुख्य कारण क्या है ?
(आय में वृद्धि-1; उच्च उत्पादकता-2; वातावरण के अनुकूल-3; कम श्रम-4; सहकर्मी किसान का प्रभाव-5; कम पानी की आवशयकता-6; कम श्रमिकों की आवश्यकता-7; ज्यादा सब्सिडी-8;अन्य-9)

Block 4: Particulars of inputs and their expenses for crop production
फसल उत्पादन के लिए इनपुट और उनके खर्च के विवरण

S.No	Inputs इनपुट	Procured from-Agency (Govt-1, Pvt.2, Other-3)एजेंसी से प्राप्त (सरकारी -1, प्राइवेट 2, अन्य -3)	Intensity (Quantity/Times) तीव्रता (मात्रा / टाइम्स)	Expenses (complete crop cycle) व्यय (पूरा फसल चक्र)
4.1	Seeds सीड्स			
4.2	Fertilizers उर्वरक			
4.3	Diesel डीजल			
4.4	Electricity बिजली			
4.5	Labour श्रमिक – own (code-1) घर के लोग(1)			
	- Hired(code-2) दिहाड़ी श्रमिक (2)			
4.6	Rent -Leased in land पट्टे पर ली हुई भूमि का किराया			
4.7	Value of hired and owned bullock labour अन्य तरीके के श्रमिक का किराया			

4.8	Irrigation सिचाई			
	Water charges paid to farmer पानी के दाम			
	Piping charges पाइप के दाम			
	Rent of borewell बोरवेल का किराया			
	Other अन्य सिचाई खर्च			
4.9	Repair of irrigation and other machinery सिंचाई उपकरणों की मरम्मत और रखरखाव हेतु खर्च			
4.10	Depreciation मूल्यहास			
4.11	Other expenses अन्य खर्च			
4.12	Total(1to8) कुल खर्च			

4.13 Any water bill/charges are paid to govt.?(Yes-1,No-2)
क्या आपने सरकार को पानी के कुछ दाम दिए हैं(हाँ-1; ना-2)

4.14 If yes, then how much?
अगर हाँ, तो कितना?

4.15Have your irrigation expenses increased over the period?(Yes-1 , No-2)
क्या पिछले कुछ वर्षो में आपके सिचाई खर्चो में वृद्धि हुई हैं? (हाँ-1; ना-2)

4.16 If you purchase water, then do you believe this is a recent phenomenon and its economically unviable?(Yes-1,No-2)आपको लगता हैं पानी खरीदना एक नयी घटना हैं और आर्थिक रूप से अभावनीय हैं? ? (हाँ-1; ना-2)

4.17 Subsidies on irrigation are received? (Yes-1, No-2)
सिचाई हेतु सब्सिडी मिलती हैं? (हाँ-1; ना-2)

4.18 Type of subsidy received (Power subsidy-1, Irrigation equipment-2, Fertilizer subsidy-3, Credit subsidy-4, Other-5)
आपको सरकार की तरफ से किस प्रकार की सब्सिडी मिल रही है? (पावर सब्सिडी-1; सिचांई उपकरण सब्सिडी-2; उर्वरक सब्सिडी-3; लोन सब्सिडी-4; अन्य सब्सिडी-5)

Code	Amount

4.19 Do you have ever taken loan for irrigation purposes? (Yes-1, No-2)
क्या आपने सिचांई हेतु लोन लिया है (हाँ-1; ना-2)

4.20 What is your usual source of loan (bank- 1, co-operative society-2, employer/landlord – 3, agricultural/ professional money lender -4, shopkeeper/trader -5, relatives/friends -6, others -7)

आपके लोन लेने का मुख्य जरिया?(बैंक -1;सहकारी समिति-2; मालिक-3; साहूकार-4; दुकानदार-5; रिश्तेदार/दोस्त-6; अन्य-7)

4.21 Is any amount outstanding currently? (Yes-1, No-2)
लोन बकायाहै? (हाँ-1; ना-2)

4.22 Specify the amount of loan outstanding
कितना लोन बकाया है?

Block 5: Particulars of Groundwater Irrigation
भूजल सिचांई का ब्यौरा

5.1	Groundwater is solely required for irrigation? (Yes-1;No-2) क्या भूजल, खेती हेतु पानी का मुख्य स्त्रोत है? (हाँ-1; ना-2)			
5.2	What is the usual depth of groundwater? भूजल की गहरायी कितनी है?	Summer	Rainy	Winter
5.3	Do you feel groundwater table has gone down? (Yes-1; No-2) क्या आपको लगता है भूजल तालिका में गिरावट आयी है?(हाँ-1; ना-2)			
5.4	If yes in q.5.3, then what do you think are three primary reasons for it? (access to technology for fetching deep waters-1; inexpensive electricity-2; inadequate canal infrastructure-3; easy and flexibility in use-4; other-5)अगर हाँ तो उसके मुख्य कारण क्या हैं?(टेक्नोलॉजी की उपलभ्धता-1; सस्ती बिजली-2; अपर्यापत नहर द्वारा सिचांई-3 उपभोग में सरलता-4; अन्य-5)	Rank1	Rank2	Rank3

5.5	Do you own any farm machinery (Yes-1; No-2) क्या कोई खेती उपकरण है स्वयं का? (हाँ-1; ना-2)	
5.5.1	Type of farm machinery owned	Yes-1, No-2
1	Pumpset (Diesel-1, Electric-2) पम्पसेट (डीजल-1; बिजली-2)	
2	Thresher थ्रेशर	
3	Power Tiller पावर टिलर	
4	Tractor ट्रेक्टर	
5	Tractor drawn equipments ट्रेक्टर चलित उपकरण	
6	Sprinklers and drip irrigation systems स्प्रिंकलर	
7	Others(please specify) अन्य	
5.6	Classification of pump (Submersible-1; Monobloc-2; other-3) पम्पसेट का वर्गीकरण (सबमर्सिबल-1;मोनोब्लॉक-2; अन्य-3)	
5.7	Pump HP (3 HP-1; 5 HP-2; 7HP-3;10 HP-4;15 HP-5; 20 HP-6; above 20 HP-7) पंप की हार्सपावर (3 HP-1; 5 HP-2; 7HP-3;10 HP-4;15 HP-5; 20 HP-6; 20 H से ऊपर-7)	
5.8	Do you know about water and energy efficient pumps? (Yes-1. No-2) क्या आपको पानी व् बिजली बचाने वाले पम्पसेटस के बारे में पता है (हाँ-1; ना-2)	
5.9	Is your pump ISI certified? (yes-1; no-2) क्या आपका पंप ISI सर्टिफाइड है? (हाँ-1; ना-2)	
5.10	Do you have a star rated pump? (yes-1; no-2) क्या आपका पंप स्टार रेटेड है?(हाँ-1; ना-2)	
5.11	Is construction of a borewell or installation of a pumpset by a neighboring farmer a threat to you? (Yes-1, No-2) सहकर्मी किसान के बोरवेल या ट्यूबवेल लगाने से आपको पानी की कमी का खतरा महसूस होता है? (हाँ-1; ना-2)	

5.12	If neighboring farmers drills deeper or drills more wells and thereby reduce your water flow, what would you do? (drill deeper-1, drill more wells-2, use powerful pumpset-3, ask him to reduce abstraction-4, practice sustainable water use or use less water-5, not do anything-6, others-7) यदि सहकर्मी किसान अपना कुआँ गहरा करता है या फिर और पंप लगता है थो आप क्या करेंगे? (गहरा ड्रिल करेंगे-1; और कुएं बनाएंगे-2; ज्यादा शक्तिशाली पंप का उपयोग करेंगे-3; उसको पानी कम निकालने को कहेंगे-4; स्वयं पानी का उचित और कम इस्तेमाल करेंगे-5; कुछ नहीं करेंगे-6; अन्य-7)	
5.13	Have there been any programmes or awareness camps in your region to conserve groundwater? (Yes-1, No-2) क्या भूजल बचाने हेतु कोई जागरूकता कैंप या प्रोग्राम हुआ है? (हाँ-1; ना-2)	
5.14	If yes in q.5.11, then by whom? (Govt-1, NGO/Society-2, Others-3) हाँ, थो किसके द्वारा? (सरकार-1; NGO/सोसाइटी-2; अन्य-3)	
5.15	Total number of such programmes you have participated in? (upto 2 = 1, 2/5=2, 5 and above=3) आपने कितने ऐसे प्रोग्राम में भाग लिया है?(upto 2 = 1, 2/5=2, 5 and above=3)	
5.16	Are you a member of any civil society/NGO /SHG etc.? (Yes-1; No-2) specify. क्या आप किसी भी नागरिक समाज / एनजीओ / एसएचजी आदि के सदस्य हैं?(हां -1; ना-2)	

Block 6: Groundwater Scarcity and pollution
भूजल की कमी व प्रदूषण

S.No.		Likert Scale Strongly agree-1; Agree-2; Neutral-3; Disagree-4; Strongly disagree-5		
			Frequency(*)	Comments
6.1		Drying of ponds and wells जलाशयों और कुआँ का सूखना		
6.2		Queuing at public taps पब्लिक नल पर लम्बी कतारें		
6.3		Purchase of water from private vendors for irrigation and other use पानी की खरीदारी खेती और घरेलु कार्य हेतु		
6.4		Distance to the principal source of water? (upto 1 km-1, 1-2kms-2, 2 and above-3) पानी का मुख्य स्त्रोत कितना दूर है? (upto 1 km-1, 1-2kms-2, 2 and above-3)		

6.5			Breakdown in public supply पानी की पब्लिक सप्लाई ना आना					
6.6			Potability of water (Normal-1, Yellow-2, Red-3, Other-4) पानी का रंग (सामान्य-1; पीला-2; लाल-3; अन्य-4)					
6.7			Water-related illness (Yes-1, No-2) पानी संबधित बिमारी हुई किसी को ? (हाँ-1; ना-2)					
6.7.1	Person ID	Name of the person नाम	Disease बिमारी	Disease Code^	Frequency कितनी बार हुई	Annual Medical Expense सालाना खर्च	Loss of Days कितने दिन काम पर नहीं गए	Loss of Wages/Income आय का नुकसान
1								
2								
3								
4								
5								
6								
7								
8								
6.8			Rising costs of supply and treatment पानी प्राप्त करने और स्वच्छ करने के लिए खर्चा बढ़ा है					
6.9			Abandonment/relocation of private boreholes/wells due to declining yields and/or declining quality प्राइवेट बोरवल बंद या दूसरी जगह ड्रिल करना पड़ा					
6.10			Relocation of farming/business and industry to more water abundant					

		areas and cities पानी की कमी की वजह से खेती या नौकरी शिफ्ट करनी पड़ी		
6.11		Falling production/ productivity खेती के उत्पादन और उत्पादकता में कमी आयी है		
6.12		Expenditure done to increase production/ productivity due to rise in irrigation cost उत्पादन व उत्पादकता बढ़ाने के लिए सिचांई खर्च में वृद्धि आयी है		
6.13		Fluctuations in land prices over the years due to water shortages भूमि के दाम में बढ़त घटत हुई है पानी की कमी के कारण		
6.14		Price of land which has a irrigation source is high वो भूमि जिस पर सिचांई का स्त्रोत उपलब्ध है वो महंगी है		

Disease Code^ Diarrhea-1, Enteric fever (Typhoid)-2, Cholera-3, Viral Hepatitis-4, others (pls. specify)-5
डायरिया -1, एंटरिक बुखार (टाइफोइड) -2, कोलेरा -3, वायरल हेपेटाइटिस -4, अन्य -5

Block 7: Groundwater and Land Inequity
भूजल और भूमि असमानता

7.1	Are there any informal arrangements organized by small-scale farmers for accessing to groundwater? (Yes-1, No-2) क्या छोटे किसानो ने कुछ अनौपचारिक व्यवस्था की है भूजल प्राप्त करने की (हाँ-1; ना-2)	
7.2	Do you think access to groundwater is equal between small-scale and large-scale farmers? (Yes-1, No-2) क्या छोटे और बड़े किसान की सामान पहुँच है भूजल तक? (हाँ-1; ना-2)	
7.3	Land integration can improve farmers' access to water and improve irrigation efficiency? (Yes-1, No-2) क्या भूमि एकीकरण छोटे किसानों की पानी और सिचांई की समस्या दूर कर सकता है? (हाँ-1; ना-2)	
7.4	How much land ownership status (small or large scale, assignees or tenant) has affected social inequity in terms of accessing groundwater and irrigation distribution systems? (High-1, Moderate-2, Low-3) भू स्वामित्व ने पानी की पहुँच और सिचांई में कितनी सामाजिक असमानता पैदा की है (उच्च-1; मध्यम-2; कम-3)	

7.5	Which obstacles exist against their water security? (Land rights-1, Caste-2, Gender-3, Govt.support-4, Economic backwardness/status-5, Others-6) पानी का हक़ सामान्य ना होने के क्या कारण हैं? (ज़मीन के अधिकार-1; जाति-2; लिंग-3; सरकारी असमर्थन-4; आर्थिक पिछड़ापन-;5 अन्य-6)	

Block 8: Averting Behaviour for managing environmental/ groundwater damage – Expenditure (भूजल की समस्याओं के प्रबंधन हेतु व्यवहार)

S.No	Coping Strategy	One time Cost (of Installation or others)	O&M Expenditure (per month)
8.1	Farm water harvesting (pond/tank construction) फार्म वाटर हार्वेस्टिंग		
8.2	Drip irrigation system ड्रिप इरीगेशन सिस्टम		
8.3	Micro-irrigation माइक्रो इरीगेशन		
8.4	Change in cropping pattern फसल पैटर्न में बदलाव		
8.5	Use of drought resistant variety सूखा प्रतिरोधी बीजों का उपयोग		
8.6	Use of water-intensive pumpsets/equipments पानी बचाने वाले पंप का इस्तेमाल		
8.7	Any other behaviour अन्य तरीके		

Block 9: Willingness to pay for managing groundwater
भूजल प्रबंधन हेतु भुगतान करने की इच्छा

You are living in an area which is water-stressed. Groundwater availability for irrigation as well as domestic use has declined over the years. In order to meet water requirements for irrigation, you are spending a major amount of income on either gaining access to groundwater or drilling deeper to maintain your current usage pattern. This situation has affected farm incomes, changed cropping patterns, and increased livelihood expenses. Hence, if a policy targeted towards this concern is made, then would you be willing to contribute financially as wells as voluntarily.

आप पानी की कमी से ग्रसित इलाके में रह रहे हैं. पिछले कुछ वर्षों में घरेलु एवं सिचांई हेतु भूजल की उपलब्धता में गिरावट आयी है। आप वर्तमान सिचांई उपयोग पैटर्न को बनाए रखने के लिए भूजल तक पहुंच प्राप्त करने या गहरी ड्रिलिंग पर बड़ी मात्रा में आय खर्च कर रहे हैं। इस स्थिति ने कृषि आय, फसलों के पैटर्न को बदल दिया है, और आजीविका खर्च में वृद्धि की है। इसलिए, यदि इस चिंता की ओर लक्षित नीति बनाई जाए, तो क्या आप स्वेच्छा से वित्तीय रूप से योगदान देने के इच्छुक होंगे।

9.1) Assessing the water related problems and focusing on improvement strategies, are you willing to pay for promoting groundwater management in your area?
(Yes-1, No-2)
अपने इलाके की पानी सम्बंधित समस्याओं को देखते हुए और इसके सुधार हेतु क्या आप कुछ भुगतान देने में इच्छुक हैं(हाँ-1; ना-2)

9.2) Would you like to pay monthly for managing groundwater?
(Interested to pay but Rs.0-1; upto Rs.25-2, Rs.50-3, Rs.75-4, Rs100-5, Rs. 125-6)
Exact amount if any:
आप कितना मासिक रूपए देने में इच्छुक हैं? (Rs.0-1; upto Rs.25-2, Rs.50-3, Rs.75-4, Rs100-5, Rs. 125-6)

9.3) if yes in question 9.1, what are the most important reasons for your willingness to pay? Rank any 3.
a) For solving current water crisis
b) For mitigating future shortages
c) Current expenditure for water use is high
d) Water security is a right
e) It is a good cause
f) Payment would coerce cooperation/ regulation in use
रूपए देने के मुख्य कारण क्या हैं?
1) वर्तमान पानी की समस्या
2) भविष्य की पानी की कमी को कम करना
3) वर्तमान में पानी प्राप्त करने के लिए बहुत ज़्यादा खर्च है
4) यह एक नेक काम है
5) रूपए देने से पानी बचाने में सहयोग और विनियमन होगा

9.4) If No in question 9.1, then what are the most important reasons for your unwillingness to pay? Rank any 3.
a) No severe water crisis
b) Current consumption is met, there is no need to need to worry about future generations

c) Current expenditure on water use is affordable

d) Do not have enough income

e) Government should pay

f) Other

रूपए ना देने के मुख्य कारण क्या हैं?

1)पानी की कोई गंभीर समस्या नही है

2)भविष्य की पानी की कमी के बारे में क्यों सोचना

3)वर्तमान में पानी प्राप्त करने का खर्च ठीक है

4)रूपए देने लायक आमदनी नहीं है

5)सरकार का काम है

6)अन्य

Investigator's Observations about the Household