EFFICIENCY AND EQUITY IMPLICATIONS OF GROUNDWATER MARKETS ON FARM ECONOMY IN WESTERN UTTAR PRADESH

By

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This is to certify that the thesis entitled, "**Efficiency and Equity Implications of Groundwater Markets on Farm Economy in Western Uttar Pradesh**" submitted to the Faculty of Post-Graduate School, Indian Agricutural Research Institute, New Delhi, in partial fulfilment of the requirement for the degree of DOCTOR OF PHILOSOPHY in Agricutural Economics by **Shri Dharam Raj Singh** embodies the results of the bonafide research work carried out by him, under my guidance and supervision. No part of the study reported here has so far been submitted any where for publication or for any other degree or diploma.

It is further certified that such help or source of information as have been availed during the course of investigation, has been duly acknowledged by him.

New Delhi,
October 7, 1997.

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Chapter 1

Introduction

Irrigation has historically played and will continue to play a critical role in agricultural development and overall well-being of many societies around the world. Since irrigation is related to the components of agricultural growth such as exploitation of yield increase, stabilization of crop yields, cropping pattern and cropping intensity, irrigation development is an important means to foster agricultural growth. More than one third of world's crop production now comes from one sixth of arable land, which is irrigated. Irrigation has therefore, been regarded as one of the most essential inputs for food security and rural development. Since the beginning of this century, there had been a significant expansion of irrigated land in the world. According to Food and Agriculture Organization (FAO), the global irrigated area increased from about 40 million hectares (mha) in 1900 to about 154 mha in 1965 and about 242 mha in 1991.

Irrigation development has always been the priority area of national agricultural development strategy, sharing credit with high yielding varieties (HYVs) and fertilizers for success of the green revolution in India. Irrigation in the past has not only enabled us to raise the crop productivity manifold, but has also played a stabilising role during drought years, as well. It is estimated that irrigation has contributed nearly sixty per cent to the growth in agricultural productivity (Seckler and Sampath, 1985). During the mid-seventies, per hectare average output (in terms of food grains equivalent) in irrigated area was thrice of that in unirrigated area (Dhawan, 1985). Irrigation is the most important factor influencing regular use of fertilizers. Even though the role played by irrigation in the success of green revolution has been very impressive, at higher yield level better water management in irrigated agriculture and soil moisture conservation in rainfed agriculture with proper plant nutrient balances will become even more important (Borlaug, 1996).

India has over thirty three per cent of its net sown area under irrigation, with groundwater and surface water contributing almost equally to gross irrigated area (GOI, 1995). This has been possible through massive investments made by public and private sectors for the irrigation development activities since independence. The nation spent more than Rs 600 billion (at 1988-89 prices) between 1951 and 1990 in the development of canal irrigation which has increased the net irrigated area from 8.6 mha in 1951 to 32 mha in 1990, thereby adding an additional irrigation potential of over 23 mha. However, canal irrigation system has suffered from various maintenance and operational inefficiencies. Only 85 per cent of created irrigation potential is actually utilised and this gap has further increased during the eighties. Cost per hectare of irrigation created is higher in canal irrigation system. Canal irrigation system also suffers from the loss of water in conveyance and application use. Water conveyance loss is estimated at 40-50 per cent which is twice than that of well irrigation (Sivanappan, 1995). Twenty per cent of area currently under canal irrigation is seriously affected by waterlogging and salinity, and 20 per cent of live storage capacity of our major and medium dams will be lost by 2000 AD implying a loss of 4 mha of irrigation potential. It is further observed that land productivity under canal irrigation is much lower than the corresponding level under well irrigation in general and tubewell in particular (Dhawan, 1988).

Groundwater is a truly scarce resource in India. It has land augmenting character. On the one hand, it enables double (sometimes triple) cropping of our land while on the other, it plays a vital role in enhancing crop yields by a sizeable multiple and in diversifying the crop mix. Farmers have the priviledge of controlling and regulating the water extraction mechanisms (WEMs). This provides a greater assurance to farmers, as the supply of water can be regulated according to his wishes, depending upon the needs of the crop to be irrigated.

Due to the above ground realities, policy makers and farmers have started giving more emphasis to the groundwater irrigation development. Although, the use of groundwater in India has been known from time immemorial, the real impetus to its use for irrigation came only after independence and particularly with the launching of the planned development programme. Notable breakthrough in the groundwater came with the introduction of high yielding variety (HYV) technology and modern groundwater extraction technology. These modern technologies are strongly complementary to each other and together result in higher production. Therefore, groundwater irrigation has become the most important and fastest-growing segment of irrigation sector. Some of this growth has resulted from public investment in deep tubewell whose performance has been pitiably low. The bulk of investment, however, has been private and installations of private tubewells have been far more effective and efficient. Private tubewells are ideally suited for meeting the rather exacting water requirements of HYVs. Therefore, there is no doubt that the private initiative which has dominated India's groundwater development in the past will continue to do so in future as well.

Although the development of groundwater potential took major strides in last three decades, only one-third of India's known groundwater potential has been developed. There are large areas in the country, where substantial reserves of groundwater are yet to be developed and brought into productive uses, except eight per cent of total blocks which are in 'dark' category (GOI, 1995). Thus, while our recent literature abounds with the problems of over-exploitation of groundwater and resultant externalities, which are doubtless in several part of the country, the main question in groundwater development at national level is still of ensuring equity and efficiency in the use of groundwater.

Private ownership of modern WEMs in India has tended to be highly skewed in favour of large farmers. In Gangetic plains, skewness in WEMs ownership is far less than in hard rock areas of southern peninsula or in areas like Gujarat where water table is very low, requiring much higher initial investment (Shah, 1993). The other reasons for the skewed ownership of WEMs are the skewed distribution and fragmentation of land holdings. A farmer must have a captive irrigable command area of a certain minimum size to earn a decent return on investment. Existing public policy does not do much to check skewed ownership of WEMs, in fact they often exacerbate it. To prevent tubewell interference and excessive withdrawals, groundwater departments, banks and electricity boards have begun to enforce siting and licensing norms seriously. However, these norms do not apply to existing modern WEMs owners. These norms favour early exploiters and penalize the late ones, a majority of whom are likely to be poor farmers. Moreover, while sitting norms seek to protect an existing modern WEM, they do not provide any protection to existing traditional well owners from modern WEMs, which in many cases, have wiped out the former. Moreover, preventing the installation of new WEM in the neighbourhood of the existing one usually strengthens the monopoly power of the owner. Resource rich farmers who use diesel engines are also unaffected by these norms.

In this gloomy scenario, the spontaneous emergence of water markets and their imaginative management offer major opportunities for equitable access to groundwater irrigation to resource poor small and marginal farmers. In recent years, evidences suggest that water markets have developed on a very large scale, though in a localized manner in South Asia. Practice of selling groundwater appears to have been prevalent in many parts of India even under traditional WEM. The earliest formal references of water selling can be traced as early as in the late sixties (Patel and Patel, 1969 and Moorti, 1970).

Water markets generate many benefits to buyers such as higher and more risk-free income flows throughout the year by increasing cropping intensity, changing cropping pattern in favour of high value crops and use of modern farming technologies. It is estimated that wheat yield per hectare of non-tubewell owners was marginally lower than tubewell owners (Shankar, 1992). Farmers using purchased groundwater obtained higher yield per hectare than tubewell owners (Sai, 1987). Average yield of wheat and paddy was greater in case of WEM owners followed by buyers from private WEMs and buyers from state tubewells (Lowdermilk *et al.*, 1978). Water markets offer an opportunity to small and marginal farmers who owned a WEM to increase WEM utilization for what their own land would permit and thereby to spread its overhead cost over a larger command area. These markets also improve wages and more employment opportunities throughout the year for farmers and labourers. It is reported that WEM owners could pump 1.5 to 4.5 times more water than they could pump in absence of water markets. Farm labour demand increased considerably after increase in buyers area under commercial crops and reducing some what seasonality in work opportunities for the landless (Shah and Raju, 1988). The cumulative benefits of water markets are larger than the said effects. The benefits will be larger and more widely distributed if water markets are efficient.

Existing literature no doubt has dealt with some major issues of groundwater markets development analysing its structure and performance, particularly its impact on agricultural production as well as its equity effects. However, most of the work have been done on the working and structure of groundwater markets. Some studies have examined the impact of different forms of water market on cropping pattern, productivity, equity and employment. A few studied the reliability and efficiency of groundwater markets. But, none of these studies could quantify the impact of water management under better form of water markets.

Our country is endowed with a vast geo-physical environment. There are fifteen agro-climatic regions where groundwater and agricultural development is significantly different. Therefore, further research is a pre-requisite to the institutionalization and development of water markets in India. It also helps to visualise the impact of water markets on the reliability of irrigation services, equitable and sustainable use of groundwater and efficiency of groundwater markets.

It is therefore, important to examine the groundwater development and subsequently the extent of operational mechanism of groundwater markets which would reflect the cropping pattern, productivity, equity and employment potential of non-owners of a WEM. Assessment of reliability and efficiency of groundwater markets and their determinants would provide feedback to policy makers, administrators, and to all those interested in groundwater development in formulating suitable strategies for equitable and sustainable utilization of this precious natural resource.

In the agriculturally advanced regions like Western Uttar Pradesh, agriculture has undergone a drastic change from self-subsistence to market oriented production or commercialized agriculture. The prevalence of groundwater markets in this region is well documented (Prasad *et al.*, 1984 and Chawala *et al.*, 1989). In the presence of small and fragmented holdings, and uneven distribution of ownership of modern WEMs, selling of groundwater is very common. Even large farmers indulge in buying and selling of groundwater. However, the above studies were confined only to the existence and functioning of these markets, and some of the crucial aspects viz., equity, employment potential, efficiency and reliability of groundwater markets were beyond the domain of previous studies. In view of the above facts, the present study on groundwater markets is undertaken in Meerut district of Western Uttar Pradesh with the following specific objectives:

1. To study the growth in groundwater development in western districts of Uttar Pradesh.
2. To examine the structure and determinants of groundwater markets.
3. To examine the effect of groundwater markets on changes in cropping pattern, productivity, equity and employment.
4. To assess the reliability and efficiency of different forms of groundwater market and suggest suitable policy measures for sustainable use of groundwater.

Plan of the Thesis

Apart from the introductory chapter, the study is organised into following chapters. Next chapter presents a comprehensive and upto date review of the relevant studies. Chapter III discusses the concept and forms of groundwater market, and methodological framework of the study. Chapter IV gives a brief description of the study area. The results of the study are presented and discussed in the penultimate chapter. The final chapter gives the summary and conclusions of the study.

Chapter 2

Review of Literature

Water has been an increasingly important factor in the development process of human civilization. It is well known that it is only paucity of water which has altered civilizations since ancient times. Even the dislodging of areas of human civilizations and habitats has occurred due to shift in availability of' water for drinking, farming and transportation. It is a key resource in agricultural production. Although the use of groundwater in India has been known from times immemorial, notable breakthrough in groundwater came with the introduction of high yielding varieties (HYVs) and modern water extraction mechanism (WEM), particularly on account of impressive private investment on this. Presently, more than 95 per cent of the area irrigated through groundwater is served by private modern WEMs in India. However, the ownership of private WEMs has tended to be highly skewed in favour of large farmers, and small and marginal farmers mostly purchase water from WEM owners.

The practice of water selling appears to have been prevalent in many parts of India even under traditional WEMs. The earliest formal references of water selling can be traced to late sixties (Patel and Patel, 1969; and Moorti, 1970). Actively functioning groundwater markets are to be found in New Mexico and California in U.S.A., Chile, Pakistan, Indonesia, Jordan, Bangladesh and many parts of India (Meinzen-Dick and Mendoza, 1996). To provide background information for formulating the objectives and appropriate analytical tools used therein, a systematic review of relevant literature that have direct or indirect bearing on the objectives of the present study is arranged here under the following sub-heads:

2.1 Groundwater development

2.2 Groundwater markets: structure and determinants

2.3 Groundwater markets: cropping pattern, productivity, equity and employment, and

2.4 Groundwater markets: reliability and efficiency

2.1 Groundwater development

Groundwater development can be examined using three sets of statistics, namely, irrigated area statistics, volumetric statistics on groundwater and statistics on water table. The irrigated area approach to groundwater development is the most convenient method as far as availability of data is concerned followed by volumetric and water table statistics.

Ashturkar (1986) computed the linear and compound annual growth rates of gross cropped irrigated area for all the agro-climatic zones of Maharashtra. The results revealed that area under irrigation had significantly increased during last two decades. The proportion of gross cropped irrigated area to gross cropped area in the state increased from 6.54 per cent in 1960-61 to 12 per cent in 1979-80.

Ministry of Water Resources, Government of India (1986) assessed the utilizable groundwater resources to be 42 million hectares meters (mham) at 24 per cent stage of groundwater development. It was estimated that the progress of groundwater irrigation development varied from 6.5 mha in 1950-51 to 28 mha in 1984-85. Similar estimates were developed by Vaidyanathan (1987) also.

Bhargava and Saksena (1989) estimated growth rates of area irrigated by groundwater in major states of India. They found that during the sixties, there was no systematic increase in the irrigated area except Bihar, M.P. and Maharashtra where increase in irrigated area was significantly high. There was a significantly increasing trend for all the states during the late seventies, but Bihar, M.P. and Maharashtra could not keep up the earlier phase of development. On the other hand, Gujarat, Haryana, Rajasthan and U.P. achieved a considerable increase. Estimated compound growth rates for gross irrigated area were significant and higher than the net irrigated area for almost all the states. They concluded that there had been greater emphasis on development of groundwater resource in the decade of 1970-71 to 1980-81.

Using area based statistics of groundwater potential and its utilization, Dhawan (1989) reported that nearly three-fourth of the ultimate groundwater irrigation potential of country was already tapped. Whereas volumetric statistics indicated that a little over one fourth of the groundwater resource had been tapped. He estimated that on full development of groundwater resources, India is capable of irrigating about 40 mha land. This view was supported by Saksena (1989) also.

Gangwar and Panghal (1989) found that only 18 per cent of total irrigated area was under tubewell irrigation in 1960-61 in Haryana. With the passage of time the percentage of total irrigated area covered by tubewell irrigation increased to 46 per cent in 1983-84. They also observed that water table was falling due to over exploitation in good groundwater quality areas while it has risen in poor groundwater quality areas. On the other hand, Joshi *et al.* (1995) recorded that in the same state, number of tubewell per thousand hectares had risen from 7 on 1966-67 to 138 by 1990-91. They also found that most of the tubewells were privately owned.

Prahladachar (1989) recorded that in Karnataka the net irrigated area increased from 18 per cent to 27 per cent by wells over the period 1955-84. The growth in irrigated area by wells was highly impressive in the sub-period from 1968-84 than prior to it. This increase was largely due to private initiative and efforts.

Sharma (1989) found that Bihar, though rich in groundwater resource had been able to develop and utilize only a small fraction of 24 per cent of this valuable resource. He reported that gross irrigated area increased more than double during 1973-74 to 1984-85. The study revealed that a good number of farmers have gone for diesel pumpsets accounting for 46 per cent of total tubewells in 1979-81 due to erratic electric supply. Similar findings were also reported by Prasad (1989).

Singh and Yadav (1989) observed that in spite of rapid increase in net draft, only one third of groundwater has been tapped in recent past for irrigation purpose in U.P.. They suggested that if remaining water balance is fully exploited, an additional area of 120 lakh hectare can be brought under irrigation.

Singh (1989) observed that before 1950 indigenous method of water extraction was prevalent in eastern U.P.. Next phase of irrigation development began with the introduction of state tubewells during the fifties and number of private tubewells began multiplying particularly after the mid-sixties.

Rao (1991) conducted a Study on groundwater development in A.P., Karnataka and Tamil Nadu and noted that more than 90 per cent blocks were in under-exploited (white) condition. Over-exploited conditions existed in many areas, including a few `white' blocks.

A study by Talukdar et al (1991) revealed that groundwater reserve in Bangladesh was in a stable equilibrium for last eight years although a continuous annual withdrawal was made at an accelerated rate.

Singh (1993) found that growth rates of canal and tubewell irrigated area were higher for pre-green revolution period followed by green revolution and post-green revolution period in Eastern U.P.. Area irrigated by other wells and by other sources was decreasing over the same periods.

Desai and Rustagi (1994) estimated that in 1962-64, nearly 29 percent of gross sown area was irrigated in upper gangetic plains region (UGPR). It was highest (nearly 45 per cent) in trans gangetic plains region (TGPR) while it was lowest (6 per cent) in western plateau and hills region (WPHR). Increment in per cent gross irrigated area between 1962-64 and 1980-82 was highest (2.7 per cent) in UGPR and TGPR, and it was negative in west coast plains and ghats region (WCPGR). The compound growth rates of gross irrigated area was estimated to be 4.4 per cent for UGPR due to high base level, 6.6 per cent (highest) for gujarat plains and hills Region (GPHR) due to low base level and negative for WCPGR.

In another estimate Dhawan (1995) noticed that groundwater development in India was only 30 per cent. It was 98 per cent and more than 37 per cent for Punjab and U.P., respectively during 1990-92 on the basis of volumetric statistics. Block level statistics revealed that only 6 per cent blocks were in 'dark' category in India during 1990-92. This composition changed over the time. In Rajasthan, `dark' blocks increased from 36 in 1982 to 63 in 1991, whereas `dark' blocks decreased from 72 in 1980 to 43 in 1988 inTamil Nadu.

Svendsen and Sinha (1995) found moderate growth in the fifties and sixties with an explosion occurring in the early seventies in well irrigated area in Bihar. Number of pumps energized in the four districts comprising the Sone Command had roughly doubled in 16 years. They also reported that in addition to total irrigated area, wells also serve as supplemental irrigation to canal water.

Estimates of GOI (1995) revealed that the groundwater resources was 45.22 mham, out of which 38.28 mham was available for irrigation purpose. Under existing water management regime the utilizable groundwater was sufficient to irrigate 80.45 million hectares.

Palanisami *et al.* (1995) in their study in Tamil Nadu found that groundwater development in tank commands was of recent origin. They observed that the number of wells in the state had more than doubled between 1960-61 and 1990-91. Swaminathan and Kandasamy (1989) also, reported that groundwater was heavily utilized in Coimbatore district of Tamil Nadu and scope of groundwater development was very limited because most of the blocks were in `dark'/`grey' category.

Mahendra and Mungekar (1996) reported that the proportion of lifting groundwater was 30 per cent in Maharashtra. In the districts such as Nasik, Jalgoan, Aurangabad, Ahmednagar, Pune, Satara, Sangli and Solapur, lifting of groundwater has gone up to 40-50 per cent. However, in Vidarbha, Konkan, as well as Marathawara (except Aurangabad district), water lifting rate were still low. They suggested that area under irrigation can be increased by using groundwater in these districts and problem of water logging in canal command area of Marathawara region can be solved by the development of groundwater irrigation.

2.2 Groundwater markets: structure and determinants

A large number of empirical studies have been conducted on structure and determinants of water markets. Some of the pertinent studies are presented below under two sections.

2.2.1 Structure of groundwater markets

A study conducted by Prasad *et al.* (1984) in Meerut district of U.P. revealed that a village had only 12 privately owned tubewells which supplied water to rest of the farmers @ Rs. 5-6 per hour. Ballabh (1989) found that as markets for groundwater has developed in Eastern U.P., they provided better and cheap access to groundwater to small and marginal farmers.

Biswas *et al.* (1986) found evidences of fierce competition between suppliers in the irrigation water markets and widespread occurance of overlapping command areas of tubewells in Bangladesh. However, they concluded that the water markets were efficient. Palmer-Jones (1989) also argued that water markets were less unsatisfactory in Bangladesh than was thought of. He found that the water markets in shallow tubewell areas were fairly competitive.

Shah and Raju (1986) recorded that few owners of WEMs did not have surplus water in A.P., but there were many owners who wanted to sell groundwater. However, they could not do so in the absence of buyers. A seller supplied water to 2.6 buyers to irrigate 8 season acres of land in addition to irrigating his own land. A large farmer served more buyers, but marginal and small farmers irrigated more of buyers' land.

Vaidyanathan (1987) reported that small farmers overcome the problems of unremunerative investment in tubewell through co-operative ownership by a group of farmers and/or sale of water. On the contrary, it was the large farmers who seem to be the main source of sale of water to others.

Shah and Raju (1988) Observed that 53 per cent tubewell owners were small and marginal farmers in A.P., and 92 per cent buyers were small and marginal farmers. As against this, in Gujarat only 15 per cent tubewell owners were from small category of farmers whereas 93 per cent buyers were from small and marginal categories. Due to high fragmentation of holding, many sellers were also buyers. Shah (1989b) reported that groundwater markets existed in Gujarat prior to 1920.

Kolavalli and Chicoine (1989) found that markets for groundwater have emerged where well owners have surplus water and high demand for irrigation water in Gujarat. Private sellers of water overcame the problem of indivisibility of groundwater investments by selling water and have provided non-well owners access to groundwater. They also found that owners were in a potential monopoly position and barrier to market entry was the investment required to construct a well irrigation system.

Prasad (1989) observed that to some extent, marginal and small farmers have got an access to groundwater utilization through the mechanism of groundwater markets in north Bihar, but there were definite limitations to the growth of groundwater markets. The improvement in agricultural performance and hence economic performance of tubewell owning farmers was quite visible as compared to water buyers. Low utilization of groundwater was due to low investment capacity, marginal land holdings of majority of farmers and lack of reliable and cheap source of energy.

Chawala *et al.* (1989) reported that in western U.P., marginal and small categories of farmers (43 per cent) get canal water and another 12 per cent get water from state tubewells. Only 13 per cent of farmers used their own tubewells and remaining 17 per cent had to irrigate their land through purchase of groundwater. In case of medium and large farmers only one per cent purchased water to irrigate their land.

Johnson (1989) argued that for those farmers who were not owners, access to the benefits of groundwater development could only be guaranteed through some form of functioning of water markets. Studies in Pakistan's Punjab revealed that groundwater was commonly sold, although such sales represent only a fraction of total amount pumped in a year. Wells were not installed primarily to sell water. Such work also suggested the ways in which water markets could be encouraged, and the forms such markets might take.

Palanisami (1989) reported that about 15 per cent of farmers in tank command owned wells acted like monopolists by exploiting the buyers by charging higher price for water and maximized their profit in Coimbatore district of Tamil Nadu. The well owners took about 38 per cent of the non-owners' income through water sales. He argued that there was an urgent need to control the monopoly behaviour of well owners so that the profit of non-well owners in the tank command can be increased.

Prahladachar (1989) found that access to groundwater could be both by ownership and/or purchase in one taluk in Karnataka. He suggested that assured markets have encouraged the small farmers to go for well irrigation and grow high value crops.

Agrawal *et al.* (1991) found that water market has been developed and competition between the users of water for different crop seasons was prevailing in Gujarat. More water was sold for cultivation of summer groundnut to small/medium farmers at a remunerative price.

Narayanamoorthy (1991) argued that the existing structure of water market could not be explained by any one of the existing theoretical market structures, but it seems more appropriate to categorize them as a monopolistic competition. He found that small farmers were not the only sellers, medium and large farmers also sold water in Pudukkottai district of Tamil Nadu. He also found that small and large farmers sold water for more hours than medium farmers. Small farmers sold a high proportion of water taken from borewell.

Raju and Rao (1991) found that all the selling firms were medium farmers and all the buyers were small farmers in North Coastal Andhra Pradesh. Buyers were limited in numbers and had no option of going to other sellers. Hence, markets were highly localized. The seller/buyers ratio was 1:2.62 in selected villages. There was no product differentiation in all the selling firms and important crops for which the water market used were sugarcane, banana, paddy and groundnut.

In a review by Vincent and Dempsey (1991) it was opined that many authors in India have promoted well development for production and equity considerations, and looked at the potential of water markets to help local water management problems. They found that in drought years groundwater purchasers faced higher price. Generally, prices were affected by access and ownership, where competition between suppliers was limited, buyers faced monopoly prices.

Reddy and Barah (1991) observed that selling and buying of groundwater was a common phenomenon in A.P., at least for one season in Chittor district and round the year in Cudapah district. More than 70 per cent of sample irrigated farmers were involved in groundwater marketing in one form or another. They have grouped farmers into four categories as: pure owners, joint owners, sellers and buyers, and found that water sellers were usually big farmers, while buyers belonged to small farm size group who can not afford to invest on a well.

Nadkarni (1992) felt that the emergence of water markets should be welcomed as a progressive development. It has made irrigation available to more people and more areas. It was also suggested that water markets should be researched in an integrated way so as to suggest measures to maximize the efficiency of use of scarce factors of production. Dhawan (1991) argued that capital costs of well irrigation can be spread out over a large crop area through rise in market sale/purchase of surplus well water. It appeared that all categories of farmers were engaged in buying and selling of groundwater activity.

Shankar (1992) reported that in eastern U.P., 16 per cent of the total tubewell owners were marginal farmers. They owned roughly 9 per cent of the total tubewells and on an average, sold water to 11 farmers. Whereas the tubewell owners holding more than 2 hectares of land were 55 per cent, owned

71 per cent of total tubewells and sold water to 8 farmers. Marginal farmers resorted to larger selling as of buyers' irrigated area constituted two-third of total irrigated area. Share of buyers' irrigated area in total irrigated area had declined on larger size of holdings. In another study Shankar (1992a) estimated that electric operated tubewell irrigated 42 per cent owners' and 58 per cent buyers' land, whereas diesel operated tubewell irrigated 73 per cent owners' and 27 per cent buyers' land. Small category of tubewell owners depended more on selling water than medium category farmers. All categories of tubewell owners were also buyers. He observed that marginal farmers accounted for 10 per cent of total water that was sold, but at the same time, they accounted for 57 per cent of all water that was purchased. Whereas medium farmers accounted for 42 percent of the water that was sold, but accounted only 3 per cent of the water that was purchased. He concluded that marginal and small farmers depended heavily on relatively bigger farmers owning tubewells for their irrigation requirements. Another interesting finding of the study was that non-tubewell owners purchases water mostly in *rabi* season. He also observed that buyers gross irrigated area decreases as farm size increases.

Prasad (1993) observed that the farm households owning pumpsets was highest (56 per cent) in the size class of above 2 ha compared to 12 per cent in marginal and 33 per cent in small category in north Bihar. On the whole 26 per cent of farm households owned pumpset which indicated poor availability of irrigation facilities. As a consequence, 55 per cent of total households hired pumpsets for irrigation purposes. As the size of holding increased, hiring of pumpsets decreased. He also observed that in marginal and other (more than 2 ha) categories, all pumpset owners were water sellers. He concluded that the structure of groundwater markets was not competitive.

Kolavalli *et al.* (1993) found that among the well owners, those with larger holdings used the wells to a greater extent than others, but those with smaller holdings irrigated their fields more intensively. They observed the existence of well developed water markets where all categories of well owner farmers sold water to buyers.

Janakarajan (1993) studied the incidence of water sale in the Vaigai basin in Tamil Nadu. Only 13 per cent sample wells reported water sales in wet lands and 3.4 per cent in dry lands. On an average each well owners sold water to about 8 acres in addition to irrigating their own lands.

Svendsen and Rosegrant (1994) cited the expansion of private sector tubewell irrigation in India, Pakistan, and Bangladesh as the most successful example of private sector irrigation infrastructure development in developing world. According to them, the emergence of successful markets for groundwater in these locations, and the unexploited positive externalities between canal and tubewell irrigation all indicated the enormous potential for expansion in this sector.

Meinzen-Dick (1995) studied the active groundwater markets in the Sone Command in Bihar and found that the proportion of groundwater purchasers was higher than the tubewell owners for all categories (except medium and large farmers). The overall proportion of buyers was inversely related to holding size. He also found that nearly one fourth of tubewell owners were buyers as well.

Swaminathan and Meinzen-dick (1995) found that farmers were trying to get access to supplemental irrigation by purchasing groundwater instead of owning wells in Periyar Vaigai project in Tamil Nadu. They reported that only four per cent tubewell owners were sellers, and nineteen percent farmers were buyers. They also found that in Lower Bhavani project, groundwater markets were totally absent.

Palanisami *et al.* (1995) observed that well owners acted like monopolists where each well owners was sole supplier of groundwater to a group of farmers located around the well.

2.2.2 Determinants of groundwater markets

Shah (1987) identified low and erratic rainfall, high depth to water table, high capital cost of tubewell installation, low WEM density, stringent spacing/licensing norms, crops using small quantity of water, absence of canal water, none or inefficiently managed or lack of state tubewells, lack of electric supply and unlined field channels for conveying water to buyers' fields as the major determinants of high monopoly power enjoyed by water sellers. Further, Shah (1988c) found that development of groundwater in mahi right bank canal in Gujarat has inverse relationship with the reliability and adequacy of canal irrigation. The water markets were in primitive stage and limited forms in the head reach than the tail-end.

Narayanamoorthy (1991) examined the relationship between sale of water and some determining factors. He found negative correlation between hours of water sale and total area as well as area under paddy and sugarcane. While positive correlation has been found between hours of water sale and total hours of water taken from the borewell, association between variables was very weak and not significant. Regression results revealed that sale of water was significantly and positively influenced by the total hours of water taken. When area under paddy of owner decreased, the sale of water increased. It was found that sale of water mostly depended upon the situational factors of the borewell such as the location of the pumpset, distance between borewells, pressure of water in borewell and the cropping pattern of the owner and the buyers.

Saleth (1991a and 1991b) quantified the relative contribution of various factors to the rental decision of farmers using 1975-76 and 1976-77 data. The estimated logit model indicated that the major factors influencing the farmers' rental and water purchasing decision were the farm size, farm assets, percentage of farm area under canal irrigation, soil fertility and untimely or delayed rainfall. The negative coefficient associated with number of fragments indicated that renting was not viable in case of highly fragmented farms. He also forecasted that small and marginal farmers were more likely to rent tubewell pumpsets than others in all the states. The rental probability was almost equal to one in Punjab and less than 0.5 in Haryana and U.P. at 100 percent canal irrigation. Its major implication was that groundwater markets benefit mostly small or marginal farmers in terms of both increasing and stabilizing farm income with lower farm assets position and low or no canal irrigation.

The factors associated with well ownership in eastern U.P. were identified by Kolavalli *et al.* (1993) using the logistic regression estimation method. They found that size of holding was a major factor influencing well ownership. Other factors like education, extent of waterlogging, soil salinity and off-farm income were not statistically significant in all the districts.

Swaminathan and Meinzen-dick (1995) found that one-third tubewell owners have shared ownership in Periyar Vaigai project area in Tamil Nadu which allow farmers with small holding to invest in wells. In lower bhavani project area 36 per cent tubewell owner shared tubewell ownership. Ninety three per cent well owners used electric operated tubewell.

Meinzen-Dick (1995) predicted probability of tubewell ownership and groundwater purchases of farmers using a logistic regression model in Sone command of Bihar. He found that land ownership, and medium and low delivery zones have a significant positive effect on ownership of tubewell. The number of plots per hectare did not have a significant effect, nor did the ratio of family size to land on ownership of tubewell. Low delivery zone and vegetable growing village had a significant and positive effect on the likelihood of water purchase. The number of plots per hectare had a significant negative effect on water purchase as a surprising result. Coefficient of land holding indicated that farmers owning more land were less likely to purchase of water, and more likely to have their own tubewells instead.

Prasad (1997) opined that bringing together small and marginal holdings into continuous blocks by consolidation would facilitate the exploitation of groundwater by these farmers by pooling their resources.

2.3 Groundwater markets: cropping pattern, productivity, equity and employment

literature pertaining to studies on cropping pattern, productivity and equity of buyers and sellers were reviewed and are given below.

A study by Lowdermilk *et al.* (1978) in Pakistan showed that average yield of wheat and paddy was greater in case of WEM owners followed by buyers from private WEMs and buyers from state tubewells.

Pathak *et al.* (1985) found that irrigation with private tubewell water supply with own as well as purchased water was distinctly more productive than state tubewell supplies in Gujarat due to high quality services.

Chambers and Joshi (1983) noted that direct subsidies to farmers increased the WEM density in Gonda district of Eastern U.P. and thereby made the water market more competitive. As a result, there was sharp increase in land productivity and total output. It also resulted in better access to irrigation for small and marginal farmers and rise in real wages especially in areas where all or part of wages were paid in kind.

The studies by Shah and Raju (1986 and 1988) found that cropping intensity was 248 per cent for sellers in A.P. while it was 238 per cent for buyers. Percentage of gross cropped area under cash crops like sugarcane, banana and tobacco was almost double for sellers as compared to the buyers. However, the number of irrigation used by buyers were normally less than that of sellers for sugarcane and tobacco, buyers obtained significantly higher yields per acre for sugarcane (330 qtls) and tobacco (15 qtls) than sellers of which were 274 qtls and 8 qtls, respectively. For other crops, buyers' yields were lower than sellers. Farm labour demand and wage rate increased considerably with increase in buyers' area under commercial crops. In Gujarat, they found that percentage of gross cropped area under cash crops was almost more than one and half times more for sellers than for buyers and percentage of same under water saving cash crops like cotton was more than double for buyers than sellers. Buyers' irrigation costs was more than double and use of water (in *kharif* and annual crops) was less than 30 per cent lower than sellers. They also observed that the buyers obtained 50-60 per cent higher yields in almost all crops than the sellers, and the average value of output per acre was more than double for sellers than buyers.

Sai (1987) examined the performance of irrigated farming based on water purchased from fellow farmers using large sample survey (LSS) data collected by National Council of Applied Economic Research. He found that the farms using purchased ground water obtained higher crop yield per hectare in all the three states. The difference was as high as 88 per cent in Gujarat.

Johnson (1989) compared the cropping intensity among tubewell owners (157 per cent), non-owners who purchased groundwater (136 per cent) and non-owners with no access to private water supplies (113 per cent) in Pakistan. Marked differences in cropping patterns between owners and non-owners were also reported especially with regards to high value crops like sugarcane, basmati rice etc.

Oad and Laitos (1989) in their study in Bangladesh reported that effective farmer participation can provide necessary control to ensure adequate and equitable distribution of irrigation water. For the objectives of equity and increased rural employment, a management model organized by groups of landless people to buy or rent shallow tubewells and sold water to others, appeared to be superior than deep tubewell owned by private individuals.

Sakthivadivel (1989) found that difference in total quantity of water applied between well owners and buyers had been only 14 per cent in Tamil Nadu. Yet paddy crop of buyers suffered due to lack of water at the critical stages of growth which resulted in depressed crop yield. The crop yield obtained was 3705 to 4817 Kg/ha for well owners and 926 to 3385 Kg/ha for water buyers. He recorded that number of irrigation applied by wells was 4-9 for owners and 1-6 for buyers in tank command.

Morton (1989) argued that some degree of inefficiency in use of irrigation equipment may be taken as an acceptable cost if it ensured a genuinely competitive water markets. There were significant equity benefits, especially when more farmers with relatively little capital gained access to the markets. He also argued that hot competition was a defence against monopoly.

Sampath (1990) found that there existed considerable inequality in India in the development and distribution of irrigation in India. Private operation in lift irrigation was more equitable in irrigation distribution than government operation in flow irrigation development and distribution. He emphasized the need for distribution across farm size groups than in terms of balanced regional irrigation development.

Agrawal *et al.* (1991) observed that more diversification of crop has been done through tubewell irrigation, and marginal and small farmers have been benefitted more than medium farmers through diversification and low rate of selling water in Gujarat.

Rajivan (1991) examined the effects of groundwater development on efficiency and equity in south-India. He suggested that groundwater has the effect of changing the basis of inequalities from location to farm size. Profits were realized from the sale of water in both the communal and private well systems.

Narayana (1991) argued that state intervention in Kerala brought about a shift from equity in communal sharing of water, which was one of the essential principles of the traditional irrigation organization to market dealings in water. This was due to energized lifting techniques owned by relatively large farmers and destruction of the traditional irrigation structure.

Prasad (1991) found certain imperfections in the existing water market system in Bihar as evident from its control by large holding class. Large variation in water charges, non-accessibility of all poor farmers to water market due to highly localized nature and discriminatory approach of the water seller for selling water to different categories of farmers were also observed. He reported that all these imperfections have not only restricted the equity effects of water market, but also showed little impact on agricultural production.

Shankar (1992 and 1992a) reported that non-tubewell owners have no difficulty in getting water in Eastern U.P., although the owners would spare water only after irrigating their own fields. He observed that the difference in wheat yield between owners and buyers was insignificant whereas in paddy yield difference was significant. Cost of cultivation of wheat and paddy at cost A, B and C were lower for buyers than tubewell owners as they did not incur any capital or maintenance cost in the operation of tubewells. He estimated that net income of wheat and paddy were negative for both owners and buyers, but the negative net income was more for the owners than buyers. He concluded that proliferation of tubewells and emergence of water markets were working in favour of non-owners who can almost apply as much water as they like.

Nadkarni (1992) noted the emergence of monopoly power over water resources in development of water markets. According to him, the assessment of impact of this monopoly in terms of equity cannot be made without taking into account the poverty and income level before the emergence of water markets. He concluded that water markets have expanded employment opportunities in agriculture and more holdings have become viable. Raju and Rao (1991) also found that employment of labour was more in areas where water markets have been developed.

Prasad (1993) assessed that only 31 per cent farmers mentioned about significant impact of groundwater markets on agricultural production. Though groundwater markets had been spreading but poor farmers were not able to take the advantage of the existence of such markets due to their inability to purchase water and lack of accessibility to groundwater. Discrimination was noticed in the selection of water buyers and price charged.

Kolavalli *et al.* (1993) identified major difference in cropping pattern that well owners devoted greater proportion of their land to the cultivation of vegetables and other cash crops than non owners in Eastern U.P.. They found that percentage of well owner farmers irrigating their paddy was much higher than farmers without wells. The difference in percentage of farmers irrigating wheat crop was negligible between well owners and others. They also noted that 72 to 80 per cent of sample farmers without wells gave less than two irrigations in paddy, while 34 to 80 per cent of well owner farmers gave more than two irrigation. In case of wheat, 71 to 76 per cent of well owners gave more than two irrigation, whereas 25 to 67 per cent of other farmers gave less than two irrigation in three districts. They also found that well owners did not always get higher net returns compared to the non- owners.

Strosser and Kuper (1994) found that the purchase of groundwater enhanced the equity in access to irrigation water, and quantity of water supply to non-tubewell owners in Pakistan. They reported that tubewell owners retained the largest share of the groundwater pumped, which was translated into a higher cropping intensity and larger areas under wheat and rice. The analysis of crop yields, however, did not show any clear difference between groups of farmers characterized by different degrees of control on the irrigation water supply.

Maskey *et al.* (1994) studied horizontal equity in terms of the equity in the distribution of irrigation water and found that in abundant water supply conditions, horizontal equity was reasonably fair between head and tail reach land. In dry season with limited supply of water, unfair distribution was evident demanding better management of irrigation water. The analysis of vertical equity showed that small farmers were more efficient than large ones in increasing productivity through the use of irrigation.

Gupta (1995) found that utilization of assured irrigation was very less at the buyers' farm as compared to the sellers. Sellers were taking several high priced crops and realised higher yields than that of buyers farm. He concluded that area under *rabi* crops was increasing as the availability of assured irrigation water with buyers was increased.

Rao (1995) found that with the introduction of tubewells under panchayat samiti management in West Bengal, cropping pattern shifted in favour of irrigated paddy during *kharif* and *boro* seasons. *kharif* irrigated paddy yield was increased more than double than rainfed paddy. Net income under tubewell cluster also increased significantly. He analyzed the data on water charges and concluded that equity was ensured between head and tail-end farmers and water supplied was directly proportional to the land owned by farmers.

2.4 Groundwater markets: reliability and efficiency

Almost assured water supply varying from owners' field to buyers' field has increased the agricultural intensity and productivity considerably besides insulating agriculture against drought. Studies on reliability and efficiency of groundwater markets have been briefly reviewed below.

Shah and Raju (1986) estimated that electric WEM owners operated 1622 hours per year and diesel WEM owner operated 1127 hour per year in A.P.. Average cost of operation per hour was Rs. 2.20 for electric and Rs. 6.38 for diesel operated WEMs. Average selling price was Rs. 3.05 per hour for electric and Rs. 7.64 per hour for diesel operated WEMs. They also found that an electric operated WEM owner operated 2177 hour per year in Gujarat. Average cost of operation of a WEM was Rs. 20 per hour and selling price was Rs. 25.50 per hour. In another study, Shah (1986) reported same type of findings except selling price, which was 25 per cent lower than total cost per hour of water extraction.

Copestake (1986) found that average costs of operation of a electric operated WEM was Rs. 3.55 perhour and a diesel operated WEM was Rs. 6.20 per hour in Tamil Nadu. Selling price per hour was Rs. 5.00 for electric and Rs. 17.00 for diesel operated WEMs. Narayanamoorthy (1991) also observed that selling price per hour was cheap in case of electric pump set (Rs 5.00) as compared to the diesel pumpsets (Rs 12.00) with equal horse power in Tamil Nadu. Price discrimination was confidentially practiced for bulk costumers.

Mandal and Palmer-Jones (1987) found that in Bangladesh, the private WEM owners as well as groups of landless water sellers enter into water based tenancy agreements in the face of intense competition. It was found that their share have been declining continuously. It has fallen from 50 per cent to 33 per cent and then to 25 per cent between 1981 and 1985. More recently, such contracts have been transacted even at 20 per cent and 10 per cent share.

Field studies conducted in different part of India by Shah (1987) indicated enormous variations among states and regions. However,there was uniformity in the prices charged within a region. He found that incremental costs of lifting water and water charges were high, where pro-rata tariff of electricity was realised. However, selling prices were low where power was charged on a flat rate linked to horse power (hp) of WEM. In another study, Shah (1989b) estimated that price charges per hour of pumping water was Rs. 25, average variable costs excluding labour was Rs. 10 per hour and contribution to fixed costs per hour of pumping was Rs. 15. Shah (1989c) also noted that as electricity tariff shifted from pro-rata to flat power tariff in Gujarat, water price charged by private tubewell owners declined between 27 to 58 per cent and resulted in substantial redistribution of irrigation surplus in favour of the resource poor water buyers.

Sharma (1989) found that in Nainital district of U.P., where the development of groundwater was high, the sale price of irrigation water was moderate on account of competition among tubewell owners. This induced farmers to reap the benefits of irrigation. He stressed the fact that more and more development of groundwater, especially through electric tubewells can be an important means of providing access to the benefits of groundwater irrigation for small and marginal farmers.

Singh (1989) noticed that inspite of spectacular growth in number of private tubewells and the general reliability of irrigation water provided by them, there remained the difficulty in access of irrigation water at critical periods particularly for buyers of small and marginal farmers in eastern U.P.. In *kharif,* particularly for paddy crop, buyers get water from the owners after transplanting period whereas tubewell owners transplanted their paddy in time. Even during the *rabi* season, the water was not easily available to every needy person because of personal preference and prejudice of tubewell owners. He also found that private diesel operated pumpsets were more reliable and flexible than other sources.

Ballabh (1989) reported three stages for community tubewells in eastern U.P.. In the first, difference in price charged per hour between member and non-member was significantly higher. In the second, this difference narrowed down due to the development of water markets. This happened because number of tubewells in the area have increased and average price charged from buyers was less than the average cost per hour in running pump.

Sakthivadivel (1989) observed that Rs. 5 to 10 per hour was charged for the operation of 5 hp electric tubewells and Rs. 15 to 20 for 5 hp diesel pumpsets and selling of water was not commercialized in Tamil Nadu. In some cases, well owners supplied water for entire crop season on contract basis to get one-third of produce.

Phansalkar (1989) reported that water company (a group of farmers) sold water to farmers at Rs. 36 to 60 for 36 hp to 52 hp electric motors payable on the spot in North Gujarat. He found that in crop sharing practice output value accrual to sellers was one and half time to 4 times more than cash payment method.

Kaul and Sekhon (1991) observed that various levels of flexibility and reliability of water supply under different sources of irrigation in Punjab. They found that these had direct bearing on input use, production, average return per rupee investment, and average return of water used.

Reddy and Barah (1991) observed that water marketing at an informal level and by oral consent did not pose any serious problem between buyers and sellers in A.P.. Water charges were Rs. 1 per hour per hp. Kind payment was prevalent for paddy and 300 Kgs of paddy was realised as water charges for irrigating one acre.

Raju and Rao (1991) found that price of water was charged on the spot in cash or after season based on number of hours the pumpset was put to use in north coastal A.P.. The rates varied from Rs. 4 to Rs. 8 per hour depending upon the size of bore, cost and demand for lifting water. The prices were found uniform in all the markets and fluctuation was not observed within the season or between seasons and from seller to seller. Bargaining was also not entertained.

Shankar (1992 and 1992b) recorded that average running of electric operated tubewells was 663 hours out of 2228 hours per year of available electricity in Eastern U.P.. Average operating hour per year of diesel operated tubewell was 177 hours. Income from sale of water per tubewell was Rs. 2154 per year and it generally rose with farm size and covered two-thirds of running costs if only cash expenses were to be taken into account.

Tietenberg (1992) argued that efficiency dictates that the allocation of replenishable water so as to equalize the marginal net benefits of water use.

Efficient allocation of groundwater required the consideration of the user cost of depletable resource. When marginal cost pricing (including marginal user cost) was used, water consumption struck an efficient balance between present and future uses.

Stiglitz (1993) found that a transition to water markets were accompanied by increased efficiency and adoption of modern irrigation technologies. In case of groundwater, inefficiency in the use of water arose from the common pool problem. Since water markets for groundwater were generally unfeasible, an alternative second best policy was to set a discriminatory tax or subsidy passed on irrigation technology and crop choices.

Janakarajan (1993) found that water charges were dominated in cash and did not vary much between wet and dry land in Vaigai basin in Tamil Nadu. Water charges depended upon the quality of water and type of energy used. A majority of non-well owner farmers were either just meeting their demand for water or faced water shortage. In Sirunavalpattu village, he found that the water purchaser gave one-third of his produce to the water seller. In addition to the payment of water, purchaser was expected to perform certain unpaid and paid services to the water sellers.

Shah and Bhattacharya (1993) found that the water companies performed significantly better than cooperatives on account of the operational and economic efficiency in Gujarat. Operating expenses was higher for companies but company earned twice than cooperatives in gross income. Its impact on profit was manifold. Organizational performance of the companies were also better than cooperatives. Average price charged by the cooperatives and companies was 15 and 4 per cent lesser than private tubewell owners, respectively.

Kolavalli *et al.* (1993) used cropping intensity and percentage of gross area irrigated as indicators of access to groundwater irrigation in eastern U.P.. They assumed that quality of irrigation available to a owner and a buyer were same and found that access was nearly same for well owners and buyers in two districts and marginally less for buyers in other two districts.

Malik (1994) quantified the long term effect of depleting groundwater table by using a natural resource accounting (NRA) framework. He found that in Punjab and Haryana 69 and 20 per cent blocks have been classified as 'dark' and `grey' respectively in rice-wheat (larger water requiring) growing districts whereas 17 and 12 per cent have been classified as `dark' and `grey' in maize-wheat (small water requiring) growing districts, respectively. He found that the cultivation of rice-wheat still continues to be more profitable after taking into account the cost of depleting natural resources. The results clearly indicated that economic analysis that excludes the value of productivity changes of natural resources over estimates the value of resource degrading farming practices.

Meinzen-Dick (1995) constructed timeliness index (timely, untimely and relative water supply) for Sone command in Bihar and found that tubewells were particularly useful in enhancing timeliness dimension of irrigation service. The contribution of groundwater to timely irrigation was greater for tubewell owners than for water buyers eventhough this difference was not significant. The ratio of timely groundwater supplied to surplus irrigation from groundwater was approximately same for tubewell owners and buyers, but it was significantly greater than for canal and rain water.

Rao (1995) reported that the requirement of all the beneficiaries during peak period were met in four tubewell clusters out of six under panchayat tubewell in West Bengal. Nearly 75 per cent of farmers responded with good and very good for equity, reliability and sustainability of water supply. Discussions with farmers revealed that they were willing to pay 60 per cent higher charges per hour if adequacy and reliability of irrigation supply are improved. He also found that in the absence of Panchayat tubewell irrigation farmers purchased water from neighbouring farmers at higher price.

Vaidyanathan (1996) found evidences of a progressive decline in groundwater tables in several parts of the country and argued that this had important economic and social consequences. As the numbers of wells tapping an aquifer increased, yield per well declined after a point. This increased the investment and operating cost per unit of water. In the absence of a credible collective institution (like joint ownership and operation, community management or a wide spread water markets) poor farmers could not hope to access well water at all. The study also highlighted the uneven emergence and spread of groundwater markets.

Chapter 3

Description of the Study Area

Knowledge about agro-climatic and agro-economic environment of the study area is essential to proceed with an agro-economic research in the right direction. It is also necessary to understand the performance, problems and prospectives of agriculture and resource endowment of the study area. This chapter therefore, provides information about agro-economic environment such as soil, land utilization, climate, cropping pattern, crop productivity and irrigation of the study area.

Uttar Pradesh is situated in northern plains of India. It falls between 23° 52' and 31°28' north latitudes and between 77°4' and 84°38' east longitudes. It is a border state of India along the foothills of the great Himalayas, having common borders with Nepal and Tibet in the north and bounded by Bihar on the east, Himachal Pradesh, Haryana, Delhi and Rajasthan on the west and Madhya Pradesh on the south. It ranks fourth with respect to area among the Indian states with an area of 294411 square kilometers. On the population front, state ranks first among states with a population of 139112 thousand and a population density of 473 persons per square kilometer. In the state, overall literacy was around 42 per cent comprising about 56 per cent for male and 25 per cent for female (Census of India, 1991).

Uttar Pradesh has been divided into 67 administrative districts which from the agricultural point of view can broadly be classified into five economic regions viz., the Eastern, Bundelkhand, Central, Western and the Hilly

Table 3.1 Demographic features and other informations of Meerut district, Western Uttar Pradesh and Uttar Pradesh (1991-92)

Particulars	Meerut	Western Uttar Pradesh	Uttar Pradesh
Geographical area (sq.km.)	3911	82167	294411
Total population (thousand)	3448	49547	139112
Population density per sq.km.	882	603	473
Population growth per annum (Per cent)	2.17	-	2.29
Literacy (per cent):			
-Total	51.30	33.32	41.60
- Male	64.47	43.82	55.73
- Female	35.62	20.84	25.31
Number of districts	-	21	67
Number of development Blocks	18	271	897
Number of villages developed	900	27928	112804

Sources: Census of India, 1991 and Statistical Diary, U.P., 1993

regions. The western region comprises of 21 districts with around 28 per cent of the total area of the state (Table 3.1). The western region is surrounded by the hilly region of Uttar Pradesh and Nepal on the north; Haryana, Delhi and Rajasthan on the west; central region of Uttar Pradesh on the east, and Madhya Pradesh on the south. The region accounts for approximately 35 per cent of the net cropped area of the state and accommodates almost same proportion of the population with a density of 603 person per square km.

Literacy rate was lower in the western region than that of the state (census, 1991). The region has nearly 74 per cent of its reported area under cultivation with a cropping intensity of 152 per cent. Among the different regions, the western region has higher (83 per cent) net cultivated area under irrigation in which groundwater irrigation accounts for over 71 per cent (Table 3.2). Although, nearly 84 per cent of the total villages are electrified in the region, only 22 per cent of private tubewells are electric operated. Of the total, 14 per cent blocks fall under 'dark' category because in these blocks net annual draft of groundwater is more than 85 per cent of net groundwater irrigation potential.

Meerut District

Meerut district falls between $28^{0}45'$ and $29^{0}16'$ north latitudes, and $77^{0}7'$ and $78^{0}7'$ east longitudes. Ganga river forms the eastern limit of the district while Yamuna river forms western limit. To its north lies Muzaffarnagar district while Ghaziabad lies to the south. The district has five tehsils and eighteen development blocks covering an area of 3911 square kilometer spread over nine hundred villages (Table 3.1). The total population of Meerut district was 3448 thousands out of which 63 per cent was rural and around 51 per cent was literate. The district has a population density of 882 persons per square kilometer (Census, 1991). The percentage of net sown area to total geographical area of the district was over 80 per cent with a cropping intensity of 159 percent.

3.1 Irrigation infrastructure development

There are three distinct crop seasons in the region. Since most of the annual rainfall occurs during the monsoon season, irrigation plays a crucial role in the multiple cropping pattern followed in Western Uttar Pradesh. The

Table 3.2 Indicators of irrigation development of Meerut District, Western Uttar Pradesh and Uttar Pradesh (1991-92)

Particulars	Meerut	Western Uttar Pradesh	Uttar Pradesh
Net sown area ('000 ha.)	311(80)	6104(74)	17216(59)
Gross cropped area ('000 ha.)	494	9305	25282
Cropping intensity (Per cent)	159	152	147
Net irrigated area ('000 ha.)	307(99)	5057(83)	11048(64)
Gross irrigated area ('000 ha.)	486(98)	7850(84)	15426(61)
Irrigation intensity (Per cent)	159	155	140
Source-wise net irrigated area (Per cent):			
Canal	26.00	20.97	29.00
Tubewell	73.55	71.11	62.70
Others	0.45	7.91	8.30
Number of tubewells (march, 1993):			
Electric operated	35263(51)	277669(22)	483238(17)
Diesel operated	33042(48)	973895(77)	2323620(82)
State	617(1)	10518(1)	28446(1)
Total	68925	1262082	2835304
Net sown area (ha) per tubewell*	4.07	4.40	5.42
Number of 'dark' blocks	4(22)	39(14)	41(5)

Source: Statistical Diary, U.P., 1993 and Groundwater Resources of India, CGWB, GOI, 1995 and Uttar Pradesh Ke Krishi Aankare, 1991-92.

Note: Figures in parentheses indicate percentage to the total.

* Deep tubewell is considered equivalent to 12.92 shallow tubewells according to prescribed command area norms of Minor Irrigation Census (1987).

development of irrigation in the western region in general and Meerut district in particular is remarkable. The net irrigated area in the western region was 89 per cent while that of Meerut was 99 per cent of the net cultivated area as against 64 percent net area irrigated for the state as a whole. Irrigation intensity which refers to gross irrigated area to net irrigated area was 158, 155 and 140 per cent for the district of Meerut, the western region and the state of Uttar Pradesh as a whole respectively (Table 3.2).

Canal and groundwater are the main sources of irrigation. Groundwater covers about 74 per cent of total irrigated area in Meerut district, 71 per cent in the western region and 63 per cent in Uttar Pradesh as a whole. The other source of irrigation is canal which supplies irrigation facility to the extent of nearly 26 per cent in Meerut district and 21 per cent in Western Uttar Pradesh. Command net sown area per tubewell is 4.07 hectare in Merrut district which is quite nearer to the Minor Irrigation Census (1987) norm of 3.87 hectares per tubewell. This command area is lower than that of the western region (4.40) and the state (5.40). However, 95 per cent of the total 'dark' blocks in the state fall in western region, the percentage of 'dark' blocks is much higher in Meerut district in comparison to western region and the state as a whole. This is a clear indication of higher exploitation of groundwater resources in the district under study as compared to other parts of the state.

3.2 Climate

Meerut district represents typically tropical climate, characterized by very hot summer (May to June) and moderately cold winter (December to January), accompanied by occasional frost in late December and January. The temperature goes up to 40 °C or more during May-June and minimum below

5 °C during January. The average minimum and maximum temperature varied between 18.3 °C and 31.2 °C in the district. Average relative humidity was 64 per cent, highest being 83 per cent during August and lowest 38 per cent during May. The average wind speed was 6.3 km per hour, highest being 8.9 km during June and lowest 3.7 km during December. The average evapo-transpiration accounts to be 1545 millimeters (mm) annually with a minimum of 43.3 mm for December and highest 225.3 mm for June (Table 3.3).

Table 3.3 Climatology of Meerut district

(1989-90)

Months	Relative Humidity (Per cent)	Rain fall (mm)	Wind speed (km/Hr)	Temperature Max. (° c)	Temperature Min. (° c)	Potential Evapo-transpiration(mm)
January	78	30.4	4.9	20.6	7.9	53.1
February	65	29.7	7.2	24.5	9.8	75.1
March	56	14.9	7.1	30.1	15.0	127.1
April	39	7.7	7.7	36.1	20.2	174.7
May	38	9.3	8.6	40.0	24.8	222.2
June	54	70.9	8.9	39.5	27.4	225.3
July	79	246.9	7.1	34.3	26.4	163.0
August	83	229.4	5.9	32.7	25.7	142.1
September	76	151.6	6.0	33.4	24.3	142.2
October	69	37.1	4.4	31.9	18.5	111.3
November	63	2.2	4.4	27.9	11.3	65.9
December	73	7.7	3.7	23.2	8.1	43.3
Annual total /Average	64	837.8	6.3	31.2	18.3	1545.3

Source: CGWB report on Meerut district, 1994.

The district receives on an average of 837.8 millimeters (mm) annual rain fall, out of which 83 per cent is received during the South-West monsoon from June to September every year. By middle of October, the monsoon recedes from the district. The monthly rain fall distribution indicates that July and August are the wettest months of the year.

3.3 Distribution of land holding

According to 1990-91 agricultural census, the average size of holding in Meerut district was 1.20 hectare as compared to 0.89 hectare for the state as a whole. A perusal of Table 3.4 shows that about 63 per cent of the total operational holdings were of the size less than one hectare. These holdings

Table 3.4 Number and area of operational holdings in the Meerut district

(1990-91)

Sl. No.	Farm size	Number	Area (ha)
1.	Marginal (Upto 1 hectare)	165679 (63.12)	70859 (22.38)
2.	Small (1-2 hectare)	50549 (19.26)	75739 (23.93)
3.	Semi-medium (2-4 hectare)	21630 (8.24)	52188 (16.49)
4.	Medium (3-5 hectare)	17395 (6.63)	65552 (20.71)
5.	Large (above 5 hectare)	7224 (2.75)	52227 (16.49)
	Total	262477 (100.00)	316565 (100.00)

Source: Uttar Pradesh Ke Krishi Aankare, 1991-92.

(marginal) accounted for only 22 per cent of the total operational area in the district. The small holdings were about 19 per cent of the total number of holdings which constituted nearly 24 per cent of the total operated area Thus, the small and marginal holdings were about 83 per cent of the total holdings and occupied just 46.31 per cent of the total operated area. About 17 per cent of the total number of holdings were 2 hectares and above, covering around 54 per cent of the total operated area in the region. Thus, Meerut district is characterized by relatively high magnitude of inequality in land distribution.

3.4 Land Utilization Pattern

Western region has mainly deep and fertile soil with some patches of saline and alkaline soils. The Meerut district forming a part of rivers Ganga and Yamuna doab, has rich fertile alluvial soil plain with gradual slope of land. Table 3.5 indicates that 79 per cent land of the district is under active cultivation out of which, 59 per cent of land grow more than one crop. Only 2 per cent of total reported area was under forest. The land under non-agricultural uses was 12 per cent. The fallow land in the district was more than three per cent, which may be developed for agricultural purposes.

3.5 Cropping Pattern

Sugarcane is the most important cash crop grown in the study area, cultivated on 34 per cent of the gross cropped area (Table 3.6). Wheat is the main food crop, grown on 30 per cent of the gross cropped area. Maize and paddy are the other important cereal crops grown (4 per cent and 3 per cent of gross cropped area of the district respectively). The other crops grown are fodder crops (14.53 per cent during *kharif,* 2.92 per cent during *rabi* and 3.25 per cent during *zaid*) and potato (1.58 per cent of the gross cropped area). Cropping intensity was 165 per cent during 1984-85 and 159 per cent during 1991-92. The decline in cropping intensity can be attributed mainly to decrease in area under foodgrains after 1984-85.

Table 3.5 Land utilization pattern of Meerut district

(1991-92)

Particulars	Area (ha)	Percentage of area to total
Reporting area	391714	100.00
Forest	7993	2.04
Land under non-agricultural uses	47317	12.08
Barren and unculturable land	6100	1.56
Permanent pastures and other grazing land	381	0.10
Land under misc. tree crops and other groves not included in net sown area	880	0.22
Culturable waste land	4959	1.27
Current fallow	568	1.45
Fallow land other than current fallow	7462	1.90
Net cultivated area	310942	79.38

Source: Uttar Pradesh Ke Krishi Aankare, 1991-92.

Table 3.6 **Major crops and their share in gross cropped area in Meerut district (1991-92)**

Crops	Area (ha)	Share in gross cropped area (Per cent)
Kharif		
Sugarcane	167377	33.89
Maize	18386	3.72
Paddy	13564	2.75
Cotton	1102	0.22
Pulses	1807	0.37
Fodder	71777	14.53
Others	6742	1.37
Total	280735	56.85
Rabi		
Wheat	146287	29.62
Barley	686	0.14
Mustard	5559	1.13
Pulses	2525	0.51
Potato	7807	1.58
Fodder	14413	2.92
Others	4117	0.83
Total	181394	36.73
Zaid		
Maize	605	0.12
Pulses	3669	0.74
Fodder	16071	3.25
Others	11365	2.30
Total	31714	6.42
Gross cropped area	493863	100.00

Source: Uttar Pradesh Ke Krishi Aankare, 1991-92.

3.6 Yield of major crops

Western region as a whole and Meerut district in particular has higher yields per hectare than the rest of U.P.. The average yield per hectare of sugarcane was 643 qtls, 33.28 qtls for wheat and 224 qtls for potato in the district during the year 1991-92 (Table 4.7). The yields of maize, paddy, black gram (urd), green gram (moong), and bengal gram were 13.52, 19.85, 9.82, 6.67 and 11.88 qtls per hectare, respectively.

Table 3.7 Yield of Major Crops in Meerut District

(1991-92)

Crops	Yield (Qtls/ha)
Sugarcane	643.04
Wheat	33.28
Maize	13.52
Paddy	19.85
Black gram	9.82
Green gram	6.67
Bengal gram	11.88
Potato	224.36

Source: Uttar Pradesh Ke Krishi Aankare, 1991-92.

3.7 Fertilizer consumption

The total fertilizer consumption in the district was reported to be 124 kgs per hectare in 1991-92. It was 103 kgs for nitrogen (N), 18 kgs for Phosphorus (P_2O_5) and 3 kgs for Potash (K_2O) per hectare.

3.8 Other Infrastructural development

The relative developmental index of Meerut district was 112 as against 72 for Uttar Pradesh and 100 for all India. There was a good infrastructure of roads and almost all the villages were connected by pucca roads. The road length per 100 square km was 90.59 km as compared to only 62.48 for the state (1993). In contrast to 100 per cent electrified villages in Meerut district and 84 per cent in western region, only 74 per cent villages were electrified in state (1991-92).

Co-operatives provide a bulk of the agricultural credit in Western U.P., though Nationalised banks too have a good penetration among farmers. The per hectare credit to agriculture in Meerut district was nearly double at Rs.1538 as compared to the state as a whole. There were 11 regulated markets comprising 5 main and 6 sub-markets in Meerut district. These markets provide a host of facilities to the farmers as well as traders. A network of 9 sugar factories and scores of cane collection centres provide a good market to purchase the sugarcane at an assured price. They also provide the latest know-how in the cane production technology besides, various inputs and extension services to the peasents.

Chapter 4

Methodological Framework

This chapter presents the methodological framework used for the fulfillment of the objectives of the study. A review of earlier studies on groundwater development and groundwater markets provided a good practical and theoretical knowledge for designing the present study and facilitated in selection of suitable methodology for the study.

The methodological details regarding the selection of the study area, sampling framework, collection of data and analytical techniques employed in the study are presented in this chapter.

4.1 Sampling design

The western region of Uttar Pradesh was purposively selected for the study on account of higher proportion of area under groundwater irrigation. Out of the twenty one districts of Western Uttar Pradesh, Meerut district with high water extraction mechanism (WEM) density was again chosen purposively. Out of the eighteen development blocks of Meerut district, Binoli and Chhaprauli blocks were selected randomly which fall under 'dark' and 'grey' category of blocks, where net annual draft of groundwater was more than 85 per cent and in the range of 65 to 85 per cent of net annual recharge, respectively.

A list of villages in each sample block was prepared with the help of Block Development Officer of concerned block and a cluster of two villages from each block was chosen, where farmers depended heavily on groundwater irrigation. A list of farmers was prepared from each sample village and 180 farm households were selected randomly from selected blocks of the district.

4.2 Collection of data

The present study is based on primary as well as secondary data. Source-wise time series data on net irrigated area under different sources and gross irrigated area were compiled from the various issues of Indian Agricultural Statistics (Volume II), published by the Directorate of Economics and Statistics, New Delhi to study the growth in groundwater development.

Primary data on various aspects of groundwater markets were collected through personal interview of the respondents with the help of specially structured, pre-tested schedule. The data pertain to the agricultural year 1994-95.

4.3 Concept and nature of water markets

The term water markets connotate a localized, village level informal arrangement through which owners of a modern water extraction mechanism (WEM) sell water to other farmers at a price. The poor farmer in the absence of a sound economic base and resource rich and big farmers due to the high degree of farm fragmentation enter into water markets as a buyer. The seller is typically a private owner of WEM with surplus pumping capacity. Generally, buyers pay for pumping of irrigation water per hour irrespective of quantity of water extracted. The payment is either on the spot cash payment or deferred payment made at the time of harvest. Water based tenancy, labour services and crop share contracts, and payment in kind are generally absent.

There are some important features of the water markets in the study area which distinguish these water markets from other kinds of markets and resource management institutions. They are:

Spontaneity: Even though the WEMs are not installed primarily to sell water, water markets come into existence by spontaneous action initiated by individual farmers to exploit a mutually beneficial opportunity. The groundwater is commonly sold and purchased, although this represents only a fraction of pumped water.

Informal: The sole basis of the whole transaction is the mutuality of needs between the buyers and sellers. There is no formal legal sanction behind the transactions in these water markets.

Unregulated: These are unregulated and the state government or state electricity board does not exercise any direct or indirect control on the manner of the working and the terms of transaction in these markets.

Localized: Water markets are mostly limited to a part of a village's land/neighbouring fields.

Fragmented: The option of one seller does not depend on the action of other sellers, but it depends upon the number of buyers and their respective area.

Non-seasonality: Water markets operate in all the three crop seasons, namely; *rabi, kharif* and *zaid*. But the transaction in water markets are relatively less in the rainy season.

Impersonal: Water markets are impersonal in the sense that sellers generally do not distinguish between various buyers in term of selling or quality of service provided on the basis of cost, political affiliation, economic or social status or family relationship. But some sellers give preference to those buyers who make on the spot cash payment for the water charges.

The practice of selling and buying of groundwater was prevalent in study area even under traditional water extraction mechanism (WEM). This practice has grown rapidly in accordance with the advent of modern WEM with its built-in indivisibility coupled with the diffusion of HYV technology wherein protective role of irrigation water in traditional farming technology gave way for a productive role of water under the modern technology.

Generally, the buyers constitute the marginal and small farmers who are resource poor and incapable of entering in partnership arrangements. Even resource rich farmers cannot install a WEM on every fragment of his holdings with the result that he often ends up purchasing water to irrigate some fragments. The major forms of water market found in the study area can be categorised as:

1. Purely buyers
2. Owners+buyers
3. Owners+buyers+sellers
4. Owners+sellers

There was another form of groundwater users in which water markets do not exist. For the purpose of a comparative analysis, this form of water users was considered as:

5. Purely owners.

1. Purely buyers

This form of water market arises mainly because of small size of holding. Buyers are generally resource poor farmers and they do not get a suitable partner to pool their resources to install a WEM. Another important reason is economic non-viability of WEM due to small and fragmented holding even when small and marginal farmers are resource rich. Some farmers who found that water charges are cheap and therefore did not feel the need for huge investment accruing in WEMs. Those farmers whose fields are near to state tubewell, buy sufficient water from them as and when required.

2. Owners+buyers

This form of water markets exists generally because of fragmentation of holdings. When the farmers install a WEM on the big fragments to irrigate only their field, the lack of surplus water for the other parcel of land or inaccessibility compels them to purchase water from the neighbouring WEM owners.

3. Owners+buyers+sellers

Existence and operation of this form of water markets is also due to high degree of farm fragmentation. On the big parcel of holding, farmers install a WEM to irrigate their field and supply surplus water to neighbouring farmers. On the other parcel of land they purchase water from the neighbour(s).

4. Owners+sellers

These farmers are owner of WEMs and their land holdings are consolidated. They sell surplus water to other farmers because their land holdings are small to utilize a WEM at full capacity and water markets offer an opportunity to spread its overhead expenses by increasing the WEM utilization.

5. Purely owners

Water market does not exist in this category of farmers because they have WEMs to irrigate only their fields. Land holdings are generally consolidated. The owners do not enter in water markets because neither they have surplus water to sell nor to buy from others.

4.4 Analytical framework

This section deals with approach and methods of analysis to test the different hypotheses of the study.

Tabular approach was followed to examine the existing resource endowment, magnitude and dimension of the groundwater markets, effect of groundwater markets on changes in cropping pattern, cost of cultivation, productivity, employment, returns from different crops, cost of water extraction and selling price of water.

Frequency distribution analysis was also used to quantify the relative significance of various factors influencing the installation of electric operated and diesel operated water extraction mechanisms (WEMs), groundwater purchasing and selling decisions of farmers. Reliability and accessibility of water under different forms of groundwater market were also assessed by tabular analysis.

4.4.1 Estimation of growth in groundwater development

Growth rates were worked out to examine the tendency of the variable to either increase or to decrease or to stagnate over the period. It also indicated the magnitude of the rate of change in the variable under consideration per unit of time. In this study, growth analysis was carried out by using the compound growth rate (CGR), as in a biological production process like agriculture, the CGR is considered to be more appropriate (Rath, 1980).

Trend lines were fitted with the exponential function as given below:

$$Y = A\ b^t \quad ...(1)$$

CGR in percentage = [antilog(log b) - 1] x 100

The growth rate was computed for groundwater irrigated area. Growth rates were also worked out for total and source-wise irrigated area. Function was fitted for the period under consideration (1955-56 to 1990- 91). To capture the temporal differences in irrigation development, above mentioned function was fitted for four different time periods, viz:

(i) the pre-green revolution period (1951-52 to 1966-67),

(ii) the early green revolution period (1966-67 to 1977-78),

(iii) the period of rapid growth (1977-78 to 1984-85), and

(iv) the period of consolidation (1984- 85 to 1990-91).

4.4.2 Determinants of water markets

In the groundwater markets, buying and selling water are dichotomous dependent variables. Determinants of these were assessed using a logit model based on logistic cumulative distribution function. The behavioural model used to examine the factors affecting the purchase of groundwater is:

$$Y_i = g\ (Z_i) \quad ...(2)$$

$$Z_i = \alpha + \beta_k X_{ki} \quad ...(3)$$

where,

Y_i = the observed response of the i[th] farmer (i.e. the binary variable, Y = 1 for buyer, and Y = 0 for a non-buyer).

Z_i = an underlying and unobserved index for the i[th] farmer (when Z exceeds some threshold Z^*, the farmer is observed to be buyer; otherwise farmer is a non-buyer).

X_{ki} = k^{th} explanatory variable of i^{th} farmer.

i = 1, 2,...,N. where, N is the number of farmers.

k = 1, 2,....,M. where, M is the total number of explanatory variables.

α = constant

β = an unknown parameter.

The logit model postulates that P_i, the probability that i^{th} farmer purchases groundwater, is a function of an index variable Z_i summarizing a set of the explanatory variables. In fact, Z_i is equal to the logarithm of the odds ratio, i.e., ratio of probability that a farmer purchases groundwater to the probability that he does not purchase and it can be estimated as a linear function of explanatory variables (X_{ki}). This can be mathematically expressed as:

$$Z_i = \ln \{\frac{P_i}{1-P_i}\} = \alpha + \beta_k X_{ki} \qquad \ldots (4)$$

Once this equation is estimated, P can be calculated as:

$$P_i = F(Z_i) = F(X_i) = \frac{1}{1-e^{-Z_i}} \qquad \ldots (5)$$

$$= \frac{1}{1+e^{-(\alpha+\beta_k X_{ki})}} \qquad \ldots (6)$$

Where,

"e" represents base of natural logarithms and approximately equals to 2.718.

In the logistic regression, the parameters of the model were estimated using the maximum-likelihood method, i.e. the coefficients that make our observed result most likely were selected. The logistic coefficient can be interpreted as the change in log odds associated with one unit change in the independent variable. Since the logistic regression model is nonlinear, an iterative algorithm was used for parameter estimation. The maximum likelihood estimation procedure has number of desirable statistical properties. All parameter estimators are consistent and also efficient asymptotically. In addition all parameter estimators are known to be (asymptotically) normal, so that the analogous of the t-test can be applied. In this case the ratio of the estimated coefficient to its estimated standard error follows a normal distribution. There are various options analogous to R^2 to assess whether or not the model fits the data.

The goodness of fit of the model was tested by three approaches. Firstly, the predictions were compared with the observed outcomes and expressed in percentage of correctly predicted. Secondly, -2 times the log of the likelihood (-2LL) estimate was used as a measure of how well the estimated model fitted the data. A good model is one that results in a high likelihood of the observed results (If model fits perfectly, the likelihood is one and -2 log likelihood is zero). To test the null hypothesis that the model fit perfectly, -2 log likelihood has a chi-square distribution with N-M degrees of freedom. In this test the large observed significance level indicates that this model does not differ significantly from the perfect model. Lastly, chi-square test was used. The difference between -2 log likelihood for the model with only a constant ($-2LL_0$) and -2 log likelihood for the current model ($-2\ LL_{max}$) follows Chi-Square (χ^2) distribution. The degrees of freedom for the Chi-Square test are the difference between the degrees of freedom for two models being used as { (N-1)-(N-M)}.

$$\text{Chi-square} = - (LL_0 - LL_{max})$$

Thus, chi-square tests the null hypothesis that the coefficient for all of the explanatory variables in the model except the constant are zero. This is comparable to the over all F-test for test of regression.

In this study, it is hypothesized that the probability of a farmer purchasing groundwater depends on the total operational holding in ha (X_1), the number of farm fragments (X_2), Source of energy (X_3), percentage of gross cropped area under sugarcane cultivation (X_4), Education in number of years of schooling completed by the farm operator (X_5), percentage of family labour to total family (X_6), percentage of non-farm income to total income (X_7), water charges per hour (X_8), and joint ownership of a WEM (X_9).

The index variable Z_i indicating whether a farmer buys groundwater or not, is expressed as a linear function of the above listed variables as:

$$Z_i = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \beta_7 X_{7i} + \beta_8 X_{8i} + \beta_9 X_{9i} + U_i \quad ...(7)$$

The same model was developed to capture the influence of factors affecting the ownership of an electric operated WEM and selling of water decisions of farmers.

Specification of variables:

Farm size

Operational holding is one of the important factors influencing purchase of groundwater. The impact of operational holding on probability of the ownership of an electric operated WEM, purchasing and selling can be captured either by own operational holding or total operational holding. However, to examine the impact on purchasing, total operational holding has been included while only owned cultivated area has been taken into consideration for ownership of an electric operated WEM and selling of water.

The total operational holding is likely to affect the probability of groundwater purchasing due to the reason that farm size and ownership of a

WEM is directly related. Therefore, a priori expectation is that the probability of purchasing of groundwater is inversely related to the size of farm and ownership of an electric operated WEM and selling of water are related to the size of farm.

Farm fragmentation

Ownership of an electric operated WEM, selling and purchasing of groundwater are crucially dependent on the degree of fragmentation of operational holding. In logit analysis, this variable can be included in number of farm fragments or in number of farm fragments per hectare. For the purpose of present study, number of farm fragments have been used because the number of farm fragments per farm did not vary with the size of operational holding.

Land fragmentation is often suggested to be an impediment to WEM ownership. With dispersed holding, it is presumed to be more difficult for a WEM to irrigate all land of a farmer than if the land is in a consolidated parcel. It is, therefore, expected a priori that a farmer with high degree of fragmentation is relatively more likely to purchase groundwater, and less likely to own an electric operated WEM and selling water.

Cheap source of energy (electricity)

There were three types of energy use to extract groundwater by farmers, viz., electricity, diesel and electricity cum diesel. In this study, electricity as a source of energy has taken the value of one otherwise zero because it is a cheap source of energy in comparison to other sources. Since electricity as a source of energy to extract groundwater variable indicate the extent of a farmer's access to cheap irrigation water, it will definitely have a positive effect on ownership of an electric operated WEM, selling and purchasing probability as no rational farmer will substitute cheap source of energy to costly one.

Installed electric horse power

Generally, farmers' owned area per WEM are not sufficient to fully utilize the capacity of WEM, farmers increases irrigated area per electric operated WEM by selling surplus water to other farmers to maximize the utilization of the capacity of electric operated WEM and to spread its overhead cost. Installed capacity of a WEM (horse power of an electric motor) per ha of owned area is included in this analysis to capture this effect. It is expected that electric motor hp per ha of owned area and selling of water have inverse relationship.

Area under high value crop: sugarcane

Sugarcane is a high water requiring crop. It is also high value crop and occupies higher percentage of gross cropped area in the study area. To capture its impact on installation of an electric operated WEM, selling and purchasing of groundwater either in terms of percentage of net cropped area under sugarcane or percentage of gross cropped area under sugarcane or area under sugarcane can be incorporated. For this purpose, percentage of gross cropped area under sugarcane was used. A farmer without WEM and with large percentage of gross area under sugarcane is relatively more likely to purchase groundwater to irrigate his crops. However, a farmer with WEM and with high percentage of gross cropped area under sugarcane may go for purchasing groundwater to irrigate his plots located farther from his WEM. Conversely, a farmer with owned WEM and with higher percentage of gross cropped area under sugarcane may not be able to spare groundwater for other needy farmers. Therefore, nature of the relationship between percentage of gross cropped area under sugarcane and probability of ownership of an electric operated WEM, selling and purchasing of groundwater can not be established a priori.

Education

Education increases the ability of a farmer to interpret, understand and modify new information. Thus, it is treated as a proxy for a farmer's managerial ability. In this study, years of formal schooling completed by head of the farm family has been used as an index for the farmer's managerial skill. It is, therefore, hypothesized that the probability of purchasing of water by a farmer is inversely related to the farmers' education. Ownership of an electric operated WEM and selling water are directly related to the farmers' education.

Family worker

Family labour provides a potential for intensive cultivation. Hence, the effect of family worker on purchasing groundwater can be recorded by family size or family size per hectare or percentage of family worker to the total family. In present study percentage of family worker to the total family has been used. A farmer with more family workers is excepted to own a WEM for intensive cultivation. If this is not possible, a farmer with more family labour may go for purchasing groundwater because he has more man power on per farm basis. Therefore, the nature of relationship between percentage of family labour to the total family and ownership of an electric WEM, selling and purchasing of groundwater and its probability can not be established a priori.

Non-farm income

Total non-farm income includes income from off-farm employment plus income from non-farm investments. As this income represents a rather stable component of farm family income, in the logit analysis percentage of non-farm income to total income has been incorporated. Steady non-farm income may help a small farm operator to achieve a level of income comparable to the large farmers. It may provide adequate resource base to install a WEM for improved agriculture. However, such a farmer will have less concentration on farming and may not like to invest heavily in agriculture. Hence, it is hypothesized that the probability of a farmer purchasing groundwater is directly related to the percentage of non-farm income of the farmer and inversely related to the ownership of an electric operated WEM and selling water.

Water price

Economic theory suggests that the water price per hour has inverse relationship with the likelihood of groundwater purchases and direct relationship with the ownership of an electric operated WEM and selling water. In this study, selling price per hour operation of an electric WEM has been used as a probable variable influencing the ownership and buying decisions of groundwater.

Joint Ownership

Joint ownership gives an opportunity to a farmer to install a WEM more readily by mobilizing the financial and physical resources to make the investment and utilize more of the WEM capacity to irrigate more area per WEM. It reduces purchasing and increases selling of groundwater by such farmers. However, joint ownership can reduce selling of water when the quality and quantity of electricity supply is poor. The impact of partnership on the likelihood of ownership of an electric operated WEM selling and purchasing can be captured by dummy variable for partnership. Therefore, it is expected that joint ownership of WEM is inversely related with probability of groundwater purchases and directly related to ownership of a electric operated WEM and selling water.

4.4.3 Measurement of equity

Any study on the problem of equity of an irrigation system should be in line with the objectives and purposes of the system, as stated and perceived by its beneficiaries. In this regard, two fairly distinct types of equity namely horizontal and vertical equities were used.

Horizontal equity

To examine the significance of impact of different forms of groundwater market on horizontal equity, the analysis of variance (F-Test) was carried out on number of irrigation applied, productivity realised, employment and level of fertilizer application as:

Null hypothesis (H_0) = $\mu_1 = \mu_2 = ... = \mu_k$, i.e. means of variable under consideration are equal under k forms of water market.

$$F_{k-1, N-k} = \frac{MS_{Mr}}{MS_E} \qquad \ldots (8)$$

where,

$$MS_{Mr}(\text{water markets mean square}) = \frac{SS_{Mr}}{k-1} \qquad \ldots (8a)$$

$$MS_E(\text{error mean square}) = \frac{SS_{Mr}}{N-k} \qquad \ldots (8b)$$

Total sum of squares (SS_{total}), water markets sum of squares(SS_{Mr}) and error sum of squares (SS_E) are computed as follows :

$$SS_{Mr} = \sum_{i=1}^{k} \frac{T_{i.}^2}{n_i} - \frac{T_{..}^2}{N} \qquad \ldots (8c)$$

$$SS_{total} = \sum_{i=1}^{k} \sum_{j=1}^{n_i} X_{ij}^2 - \frac{T_{..}^2}{N} \qquad \ldots (8d)$$

$$SS_E = \sum_{i=1}^{k} \sum_{j=1}^{n_i} X_{ij}^2 - \sum_{i=1}^{k} \frac{T_{i.}^2}{n_i} \qquad \ldots (8e)$$

where,

X_{ij} = factor level of the j[th] farmer under i[th] form of water markets

$T_{i.}$ = total factor level under i[th] form of water markets

$T_{..}$ = grand total of factor under consideration

N = total sample size

n_i = sample size under i[th] form of water markets

i = 1, 2,...., k

j = 1, 2,...., n_i.

If estimated F value is greater than the tabulated F value at k - 1 and N - k degrees of freedom and α level of significance, we reject the null hypothesis and conclude that means of factor under consideration among different forms of water market differ significantly.

If the means of variable under consideration under different form of water markets differed significantly in analysis of variance test, the source of such differences between any two forms of water market were determined by **Scheffe's method of multiple comparisons** (Maskey *et al.*, 1994), because of its following features:

1. It is known to be affected very little even when the populations involved are not normal and do not have equal variances which is the basic assumptions underlying the analysis of variance test.

2. Since it requires larger differences between means of significance than most of the other methods. This test is better suited for pair-wise comparisons of means.

To apply this method first define the term "contrasts".

Let μ_1 , μ_2 , ... μ_k be the means of k forms of water market. Any linear function of the form:

$$\sum_{i=1}^{k} a_i \mu_i \qquad \ldots . (9) \qquad where , \quad \sum_{i=1}^{k} a_i = 0$$

is called a linear contrast.

The purpose of a linear contrast is to make comparisons among the means. A method was developed for testing the hypothesis of the following form:

$$\sum_{i=1}^{k} a_i \mu_i = 0 \qquad \ldots . . (10)$$

Two forms of water market; i.e. purely buyers (B) and purely owners (0) may be compared by testing the hypothesis (H_0):

$$\mu_O - \mu_B = 0$$

Scheffe's method of multiple comparisons consists basically of forming what is termed as Scheffe-type confidence interval on the contrast of interest as:

$$\sum_{i=1}^{k} a_i \overline{X_{i.}} - L \leq \sum_{i=1}^{k} a_i \mu_i \leq \sum_{i=1}^{k} a_i \overline{X_{i.}} + L \qquad \ldots (11)$$

and

$$L^2 = (k-1) f_{\alpha,\, k-1,\, N-k} MS_E \left(\sum_{i=1}^{k} \frac{a_i^2}{n_i} \right) \qquad \ldots (12)$$

where,

$f_{\alpha, k-1, N-k}$ = critical point used in rejecting

MS_E = error mean square from ANOVA

$\overline{X_{i.}}$ = factor mean under i^{th} form of water markets

We conclude that there is a significant difference between the means of factor under consideration under any two forms of water market, if the numerical interval so constructed at the appropriate α level of significance does not contain zero.

Vertical equity

For the purpose of capturing the vertical equity in order to access of groundwater to farmers under all forms of water market, land productivity-farm size relationship was tested by estimating the coefficient of land by Cobb-Douglas production function of the following type (Maskey *et al.*, 1994):

$$Log \frac{Y}{X_i} = A + b_i \log X_i \qquad \ldots (13)$$

where,

Y = total crop output

X_i = size of holding

A = constant

b_i = elasticity of land

This type of equation was used because of ease and uniqueness of interpretation of regression parameters in bringing out the relationship between size of holding and productivity. A negative elasticity parameter b_i indicates equal access to groundwater, in which level of productivity declines as the size of holding increases; a zero value for b_i indicates a lack of association between farm size and access of groundwater. A positive value indicates some degree of inequitable access in which productivity increases with the size of holding.

Productivity of sugarcane and wheat was taken as the indicator for the fairness of equal access to groundwater, together with other inputs. Here, it is hypothesized that if large farmers have a fairly better access to groundwater, then this group should have a positive relationship between farm size and productivity.

4.4.3 Resource productivity

The resource productivity analysis was carried out using production functions. The linear, quadratic and Cobb-Douglas types of production functions were fitted by least square method for wheat and sugarcane crops and the appropriateness of the production function was judged on the basis of coefficient of determination (R^2). Cobb-Douglas form of production function was found to be the best fit in examining the resource productivity under different forms of water market. This production function was specified as:

$$Y = \alpha X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} \qquad ...(14)$$

where,

Y = total output of crop in quintals

X_1 = area under the crop in hectares

X_2 = human labour used in man days

X_3 = number of irrigation applied, and

X_4 = fertilizer (plant nutrients) applied in kgs

Simple zero-order correlation matrices were worked out for per farm production function of each crop and it was observed that in all the cases, there existed a high magnitude of correlation between inputs, i.e. the independent variables were highly correlated ($r > 0.70$) with each other. Due to the presence of multicollinearity among the independent variables, the estimation of the independent effect of individual input on the output was not possible. Therefore, the variables were transformed on per hectare basis and the size effect was removed. The transformed production function (per hectare production function) is specified as follows:

$$y = a\, x_1^{b1}\, x_2^{b2}\, x_3^{b3} \qquad ...(15)$$

where,

y = output per hectare of crop in quintals

x_1 = human labour used per hectare in man days

x_2 = number of irrigation applied and

x_3 = fertilizer (plant nutrients) used per hectare in kgs

The zero-order correlation matrices worked out of the above transformed data indicated that multicollinearity had been eliminated to a great extent.

4.4.5 Economic evaluation of water markets

For any production function, the total change in output is brought about by the shifts in the parameters and by changes in the value of inputs. The increase in the level of crop output under one form of water markets over the other form of water markets using the same level of inputs can be attributed to management of irrigation water. This contribution of irrigation water management can be measured by observing changes in the scale parameter and slope parameters of the production functions. The shift in intercept term of the production function measure the neutral component of water management and the shift in slope parameters in the production function measures the non-neutral component of irrigation water management. Adding both the components together, one gets an approximate measure of water management contribution to the difference in yield between different forms of water market. Output growth as a result of efficient form of water markets takes place in two stages. First, more output is made possible from the existing resource base under the production function for a crop grown under efficient form of water markets. Secondly, an adjustment component of water management is evident in movement along with production function. This is due to the disequilibrium, caused by production relationship under the efficient form of water markets. In this section, the model which captures the effects of both stages is developed. The first stage will measure contribution of better water management and second stage will measure the contribution of change in level of inputs.

Yield Decomposition model

Decomposing the difference in yield between the two forms of water market due to irrigation water management and changes in the level of human labour, irrigation and fertilizers, the per hectare production function was specificed as:

$$Y = A\, N^a I^b F^c \qquad \ldots(16)$$

where,

Y = output per hectare of crop in quintals

N = human labour used per hectare in man days

I = number of irrigation applied and

F = fertiliser (plant nutrients) used per hectare in kgs

The per hectare production function (16) for a crop under i^{th} form of water markets can be written in the log-linear form as:

$$\ln Y_i = \ln A_i + a_i \ln N_i + b_i \ln I_i + c_i \ln F \qquad ...(17)$$

In the same way, per hectare production function for the same crop under j^{th} form of water markets can be written as:

$$\ln Y_j = \ln A_j + a_j \ln N_j + b_j \ln I_j + c_j \ln F_j \qquad ...(18)$$

Where, Y_i and Y_j are the per hectare output in quintals under i^{th} and j^{th} form of water markets, N_i and N_j are the per hectare human labour used in man days under i^{th} and j^{th} form of water markets, I_i and I_j are the number of irrigation used under i^{th} and j^{th} form of water markets, F_i and F_j are the per hectare chemical fertilizers used under i^{th} and j^{th} form of water markets and A_i and A_j are the scale parameters of i^{th} and j^{th} form of water markets, respectively.

Taking the difference between production equation (17) and (18), and adding same terms and subtracting the same terms, the decomposition equation can be written as:

$$\begin{aligned}\ln Y_j - \ln Y_i = {} & (\ln A_j - \ln A_i) + (a_j \ln N_j - a_i \ln N_i + a_j \ln N_i - a_j \ln N_i) + \\ & (b_j \ln I_j - b_i \ln I_i + b_j \ln I_i - b_j \ln I_i) + \\ & (c_j \ln F_j - c_i \ln F_i + c_j \ln F_i - c_j \ln F_i) \qquad ...(19)\end{aligned}$$

The equation (19) can be rewritten as:

$$\begin{aligned}\ln Y_j - \ln Y_i = {} & (\ln A_j - \ln A_i) + [(a_j - a_i)\ln N_i + (b_j - b_i)\ln I_i + (c_j - c_i)\ln F_i)] \\ & +[(a_j (\ln N_j - \ln N_i) + b_j (\ln I_j - \ln I_i)+ c_j (\ln F_j - \ln F_i)] \qquad ...(20)\end{aligned}$$

This equation can also be rewritten as:

$$\ln \frac{Y_j}{Y_i} = \ln \frac{A_j}{A_i} + [(a_j - a_i) \ln N_i + (b_j - b_i) \ln I_i + (c_j - c_i) \ln F_i] + [a_j \ln \frac{N_j}{N_i} + b_j \ln \frac{I_j}{I_i} + c_j \ln \frac{F_j}{F_i}] \qquad \ldots (21)$$

The equation (21) decomposes the total difference in yield per hectare between farms under the two forms of water market. The bracket expression on the left hand side of the decomposition equation (21) is a measure of the percentage change in yield with the introduction of j^{th} form of water markets. The first expression on the right hand side is a measure of percentage change in yield due to shift in scale parameter A of the production function. The second expression gives the sum of difference in yield elasticities weighted by the natural logarithm of the volume of that input used in i^{th} form of water markets. This gives a measure of change in yield due to shifts in slope parameters of the production function. The third bracketed expression is the sum of natural logarithm of the ratio for each input under j^{th} and i^{th} forms of water market weighted by the yield elasticity of that input in the j^{th} form of water markets. This expression is a measure of change in yield due to changes in the use of per hectare human labour, number of irrigations and chemical fertilizer between different forms of water market.

The change in yield due to management of irrigation water is estimated by adding the values of the first (natural component of water management) and second bracketed expression (non-natural component of water management) on the right hand side of the decomposition equation (21).

Estimation of managemental gains

Following Schultz (1958), the value of inputs saved under one form of water markets over other form of water markets is treated as benefit of better management of irrigation water. Y_j is the per hectare output with j^{th} form of water markets and Y_i is the per hectare output with i^{th} form of water markets and j refers to better water managed form of water markets over i^{th} form of water markets . The value of inputs saved per hectare is measured as follows:

$$C_i = [1 + \frac{r}{100}] C_j \qquad ...(24)$$

$$S_r = [\frac{r}{100}] C_j \qquad ...(25)$$

or

$$S_r = C_i - C_j$$

Where,

S_r = the value of inputs saved (benefit) per hectare.

C_j = value of human labour, irrigation and chemical fertilizers used in producing Y_j with j^{th} form of water markets.

C_i = value of human labour, irrigation and chemical fertilizers used in producing Y_i with i^{th} form of water markets .

r = the percentage change in yield due to better water management. This is obtained by adding the values of first and second expression on the right hand side of the decomposition equation (21).

This was the broad methodological framework employed to analyse the data in fulfilling the objectives of the study.

Chapter V

Results and Discussion

The groundwater development has undergone dramatic changes in the recent past. One of the most significant changes has been the growing private investment in groundwater extraction in India. However, the private investment in modern water extraction mechanisms (WEMs) tends to be highly skewed in favour of large farmers who have evolved over time as water sellers, while resource poor marginal and small farmers are generally water buyers. There are instances when even large farmers whose land holdings are highly fragmented, resort to buying groundwater from their neighbours because it is neither feasible nor economically viable to install WEMs on each fragment of land. This dynamics has contributed mainly to the development of various forms of groundwater market in the study area.

Water availability under different forms of water market has given rise to many issues related to groundwater development such as resource endowment, structure and determinants of water markets and their effect on changes in cropping pattern, productivity differences, costs and returns structure, equity, employment, reliability and efficiency. The present chapter addresses these issues in study area. The results have been presented under four sections. Section one examines the ground water development and issues related to the development of the irrigation infrastructure. The background information and resource endowment of sample farms, and the structure and determinants of groundwater markets are dealt in the second section, while the section third deals with the issues related to cropping pattern, productivity, equity and employment among different forms of water market. The reliability and efficiency aspects of water markets are examined and discussed in the fourth section.

5.1 Groundwater and other irrigation infrastructure development

In this section, growth in groundwater (tubewell+other wells) development in western districts of Uttar Pradesh has been examined and discussed in detail. Growth in irrigated area and source-wise irrigated area have also been examined and discussed separately in order to measure the changes in irrigation infrastructure over time. To capture the temporal changes in irrigation development under broad periodic classification, each referring to different phases of agricultural development, the study period was divided into the following sub-periods:

1. the pre-green revolution period (1951-52 to 1966-67),
2. the early green revolution period (1966-67 to 1977-78),
3. the period of rapid growth (1977-78 to 1984-85), and
4. the period of consolidation (1984-85 to 1990-91)

The data for Ghaziabad district pertains to the time period from 1977-78 to 1990-91, and that for Haridwar and Firozabad districts from 1989-90 to 1990-91. Therefore, irrigated area of these districts was merged with the parent districts and the aggregate growth rate worked out for them.

For presentation and discussion of results, all the districts of western U.P. were classified into three groups based on the proportion of net sown area irrigated during the year 1951-52, the base year for the purpose of the study.

Group I : This group includes all those districts which had more than 50 per cent of their net sown area under irrigation during 1951-52. Muzaffarnagar, Meerut, Bulandshahr, Aligarh and Mainpuri districts belong to this group.

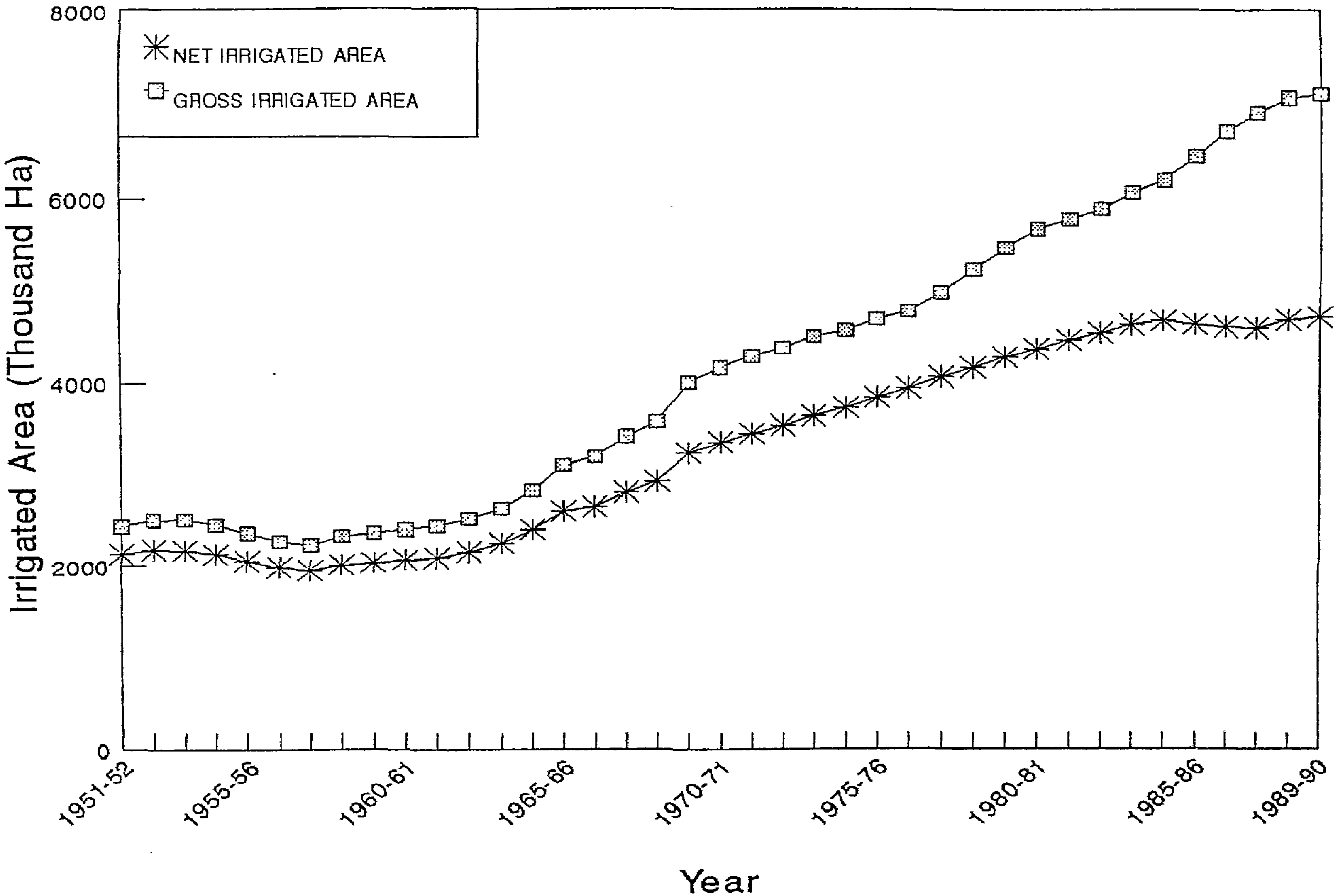
Group II: This group represents all those districts which had irrigated area in the range of 25 to 50 per cent of their net sown area in the base year. Saharanpur, Mathura, Agra, Etah, Farrukhabad and Etawah districts belong to this group.

Group III: Moradabad, Rampur, Bijnor, Bareilly, Buduan, Shajahanpur and Pilibhit districts constitute this group. These districts had less than 25 per cent of their net sown area under irrigation during 1951-52.

The districts belonging to the first group were comparatively well-developed as early as in 1951-52 as far as the irrigation infrastructure was concerned. The districts belonging to the second group, though were comparatively less developed than the first group, were more developed than the third group. The last group was the least developed as far as the irrigation infrastructure was concerned. For instance, hardly 10 per cent of net sown area of Rampur district was irrigated in 1951-52, while it was as low as 14 per cent for Bijnor (Annexure-I). These differences in the development of the irrigation infrastructure continued to influence the irrigation development pattern in the region during the later years.

5.1.1 Irrigation development

The net irrigated area in the region was increasing over years (Figure 5.1.1). This Figure shows that though the net irrigated area was stagnant up to 1962-63 and then showed an upward trend, the increase was more pronounced between 1964-65 and 1984-85. The net irrigated area in the region



Trend in irrigated area
in Western Uttar Pradesh

Table 5.1.1 Compound growth rates (%) of net irrigated area development in Western Uttar Pradesh

Districts	1951-52 to 1966-67	1966-67 to 1977-78	1977-78 to 1984-85	1984-85 to 1990-91	1951-52 to 1990-91
		Group I			
Muzaffarnagar	1.11*	1.72*	0.74*	-1.37	1.56*
Meerut	0.81*	1.27*	0.95*	-0.32	1.14*
Bulandshahr	0.45	2.32*	1.52*	-1.11	1.49*
Aligarh	0.57	1.99*	1.29*	0.35	1.79*
Mainpuri	0.00	2.63*	1.57*	2.15*	2.20*
		Group II			
Saharanpur	1.88*	4.81*	2.15*	-0.19	3.44*
Mathura	0.65	4.06*	2.30*	1.64*	2.46*
Agra	1.35**	3.90*	1.78*	1.73*	3.03*
Etah	0.70	2.50*	2.34*	1.37**	2.07*
Farrukhabad	1.20**	3.38*	1.92*	2.12*	2.77*
Etawah	1.35*	3.88*	0.25	2.23	2.18*
		Group III			
Moradabad	3.72*	5.63*	4.23*	-2.96	4.43*
Rampur	6.98*	11.06*	4.48*	-0.19	8.62*
Bijnor	3.59**	5.84*	3.07*	0.83	5.97*
Bareilly	2.89**	5.55*	2.46*	0.13	4.78*
Budaun	2.22**	5.59*	2.31**	3.92*	4.22*
Shahjahanpur	1.67	9.47*	4.04*	0.70	5.94*
Pilibhit	0.29	9.73*	6.23*	-2.42	6.92*
Western U. P.	1.24**	3.76*	2.20*	0.26	2.79*
Uttar Pradesh	1.04*	3.12*	2.53*	0.66	2.41*

* and ** indicate significant at 1% and 5% level, respectively.

had increased from 2140 thousand hectares (ha) in 1951-52 to 2855 thousand ha in 1966-67, which further increased to 4042 thousand ha in 1977-78 and 4727 thousand ha in 1984-85. By 1990-91, the net irrigated area went up to 4743 thousand ha, registering a increase by 2.22 fold in the irrigation development over the years (Appendix II).

The western region showed much higher growth in the net irrigated area than that of the state as a whole during the period under study (Table 5.1.1). There has been a significant growth in net irrigated area during first three phases of agricultural development, while the last phase showed a stagnation. The growth was relatively more during the period of early green revolution and the period immediately succeeding it, and it decelerated towards the later periods of green revolution (1984-85 to 1990-91). The same trend was noticed for the state as a whole. The comparison of growth in net irrigated area between western region and the state as a whole revealed that the first two periods witnessed relatively higher rate of growth in the western region than that of the state.

The growth in net irrigated area was higher for the districts belonging to the third group, followed by the districts in the second group. The growth rate was lowest in the districts which already had more than 50 per cent area irrigated as early as 1951-52 in (the first group). In other words, the districts with higher created irrigation potential in the early stages would have slower growth in later stages than the districts having lower created irrigation potential.

The sub-period wise comparison also showed a similar pattern, except during the period from 1984-85 to 1990-91. During this period, three districts each from the first (Muzaffarnagar, Meerut, and Bulandshahr) and third group (Moradabad, Rampur and Pilibhit) and one from the second group

Table 5.1.2 Compound growth rates(%) of gross irrigated area development in Western Uttar Pradesh

Districts	1951-52 to 1966-67	1966-67 to 1977-78	1977-78 to 1984-85	1984-85 to 1990-91	1951-52 to 1990-91
		Group I			
Muzaffarnagar	1.32*	1.94*	1.83*	0.47	2.33*
Meerut	1.13*	1.25*	2.70*	0.33**	1.79*
Bulandhahr	0.60	3.03*	3.51*	1.70**	2.55*
Aligarh	0.96	1.58	2.45**	1.88**	2.38*
Mainpuri	0.79	2.93*	2.02*	3.87*	2.62*
		Group II			
Saharanpur	2.36*	5.19*	3.18*	0.54**	4.43*
Mathura	1.14	3.41*	2.53*	1.99**	2.84*
Agra	1.32**	3.66*	1.72**	2.74**	3.10*
Etah	0.80	2.32*	2.74*	4.05*	2.48*
Farrukhabad	1.25**	3.06*	1.98*	4.08*	2.98*
Etawah	1.45*	4.49*	1.21*	2.26*	2.92*
		Group III			
Moradabad	4.39*	5.36*	5.56*	2.84*	5.65*
Rampur	7.40*	11.76*	5.96*	5.11*	10.14*
Bijnor	3.98**	6.43*	4.06*	2.15**	6.65*
Bareilly	3.67**	5.80*	3.30*	4.24*	5.86*
Budaun	2.30**	5.04*	2.84*	4.90*	4.45*
Shahjahanpur	2.10	9.75*	5.41*	3.78*	7.18*
Pilibhit	1.10	10.42*	7.01*	2.66*	8.54*
Western U. P.	1.52*	3.75*	3.21*	2.44*	3.46*
Uttar Pradesh	1.48*	3.27*	4.14*	2.58*	2.98*

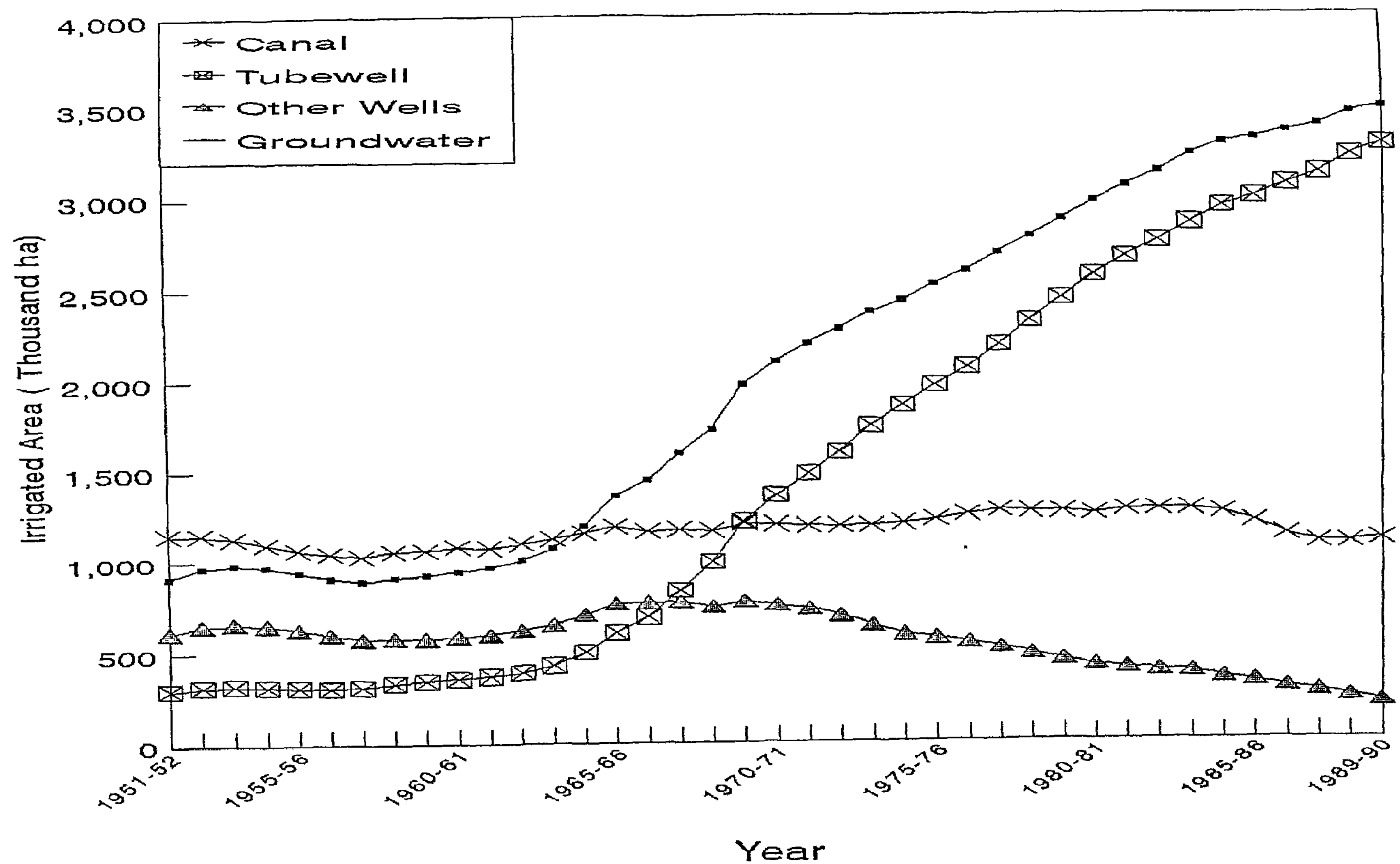
* and ** indicate significant at 1% and 5% level, respectively.

(Saharanpur) exhibited negative growth rate though statistically non-significant. It was indicative of the plateau reached in the exploitation of the irrigation potential. This is attributed to the fact that there is decline in investment particularly public investment in surface irrigation development. Secondly, the possibilities of increase in net irrigated area has almost exhausted and the area under non-agricultural uses have been increasing. This has resulted in a shift from irrigated area also. For instance, the area under non-agricultural uses has increased from 2179 thousand ha in 1977-78 to 2447 thousand ha in 1990-91, representing 12.30 per cent increase. It was as high as 21 and 28 per cent for Muzaffarnagar and Ghaziabad districts of western region. The conversion from agricultural land to non-agricultural uses on account of urbanisation and industrialisation is prevalent in most of the districts of Western Uttar Pradesh.

The gross irrigated area in the region was almost stagnant till the year 1962-63 and thereafter it showed a steady increase over the years (Figure 5.1.1). The growth in gross irrigated area for the region also followed the same pattern as exhibited by the growth in net irrigated area. The comparison among the sub-periods also gave a similar pattern to net irrigated area except during the period of consolidation. It witnessed a significant growth in gross irrigated area for almost all the districts, though very few districts registered significant growth in net irrigated area during the period of consolidation. This trend implied that the creation of additional irrigation potential decelerated in net terms but utilisation of created irrigation potential continues to increase.

5.1.2 Source-wise irrigation development

It is apparent from the Figure 5.1.2 that the source-wise irrigated area showed a spectacular trend. The area irrigated by all the sources was almost



Trend in source-wise net irrigated area
in Western Uttar Pradesh

stagnant till 1962-63, thereafter the area irrigated by groundwater in the region was steadily increasing over the years. The groundwater irrigated area increased from 955 thousand ha in 1951-52 to 3520 thousand ha in 1990-91, registering an 3.68 fold increase. On the contrary, the area irrigated by canal showed declining trend since mid-eighties.

5.1.2.1 Canal irrigation development

The comparison of growth in canal irrigated area between the western region and state as a whole showed that all the periods witnessed comparatively higher rate of growth in the state than that in western region (Table 5.1.3). It clearly indicates that after independence relatively higher investment in the surface irrigation development had gone in other regions of the state in comparison to the western region.

Although the region had registered a low but significant growth during the period under study, the sub-period wise analysis depicted a mixed trend. The first three periods (1951-52 to 1984-85) witnessed a stagnation in canal irrigated area. However, it exhibited a negative growth rate in the consolidation phase (1984-85 to 1990-91). It was on account of various factors. Some of them were; firstly, the canal irrigation water was not considered reliable by the farmers in general due to the uncertainty involved in the water release by the command area authorities. Secondly, the tail-end users in particular had the problem of poor accessibility. With the development of groundwater by farmers through their private investment, they started depending more on this reliable source of irrigation, leaving the dependency from un-reliable source of canal water. The increased urbanisation and industrialisation on the area which were under the canal command had also contributed to reduction in canal irrigated area.

Table 5.1.3 Compound growth rates(%) of net irrigated area by canal in Western Uttar Pradesh

Districts	1951-52 to 1966-67	1966-67 to 1977-78	1977-78 to 1984-85	1984-85 to 1990-91	1951-52 to 1990-91
		Group I			
Muzaffarnagar	0.40*	-0.74*	-0.81*	-1.12*	-0.36*
Meerut	-0.07	-1.35*	-1.14*	-2.29**	-0.88*
Bulandshahr	-0.61*	-0.31	-0.18	-2.48*	-0.87*
Aligarh	-0.27	-0.38	-1.24**	-2.65*	-0.39*
Mainpuri	-0.39	1.66*	-0.001	-1.02	0.64*
		Group II			
Saharanpur	0.55**	0.29	0.70	-1.55**	0.62*
Mathura	0.45	1.51	0.39	0.10	0.43*
Agra	1.46*	-2.97*	1.65	-3.44	-0.71*
Etah	-0.77	-0.74	0.18	-2.99*	-0.29*
Farrukhabad	-0.60	-0.99	-0.94	0.20	-0.70*
Etawah	0.89*	3.38*	0.68	0.82	1.18*
		Group III			
Moradabad	-0.07	11.34*	2.08	-7.52	2.81*
Rampur	7.20*	5.74*	1.49	-7.61*	4.93*
Bijnor	0.28	-2.43	2.86	-15.78	0.21
Bareilly	1.64	1.86**	-1.45	-4.52	1.67*
Shahjahanpur	0.67	3.87*	1.65	-10.97	1.81*
Pilibhit	-0.02	3.42**	3.25*	-1.33	3.52*
Western U. P.	0.27	0.56	0.11	-2.16	0.24*
Uttar Pradesh	1.58*	2.35*	2.01**	-0.93	1.79*

* and ** indicate significant at 1% and 5% level respectively.

It is interesting to note that the decline in canal irrigation was substantially higher in the districts falling under group III where the groundwater development in the subsequent years was highest. The decline in the share of public investment in agriculture in general, and that in canal irrigation in particular contributed to further reduction in canal irrigated area.

5.1.2.2 Groundwater irrigation development

The growth in groundwater (tubewells and other wells) irrigated area was higher for the western region than that of the state during the study period (4.44 and 3.39 per cent respectively). The western region had a higher growth during pre and early green revolution periods and lower growth during the later periods of the study than that of state as a whole (Table 5.1.4).

Pilibhit district belonging to the Group III depicted the highest growth in groundwater exploitation with an annual growth rate of 16.87 per cent per annum during the period 1951-52 to 1990-91. Rampur was second (10.32 per cent), followed by Bareilly (9.92 per cent) and Bijnor (6.95 per cent) in that order. The rest of the districts of Group III maintained a growth rate above 4 per cent. The districts belonging to the Group II also recorded an impressive annual growth rate above 4 per cent except than of Etah. The Muzaffarnagar and Mainpuri districts belonging to Group I had achieved an annual growth rate of as high as 4.02 and 3.50 per cent, respectively.

The period-wise examination of growth in groundwater development revealed that the early green revolution period exhibited the maximum growth, but decelerated towards the later periods of the study. During the consolidation period, Muzaffarnagar and Bulandshahr districts of Group I,

Table 5.1.4 Compound growth rates(%) of net irrigated area by groundwater in Western Uttar Pradesh

Districts	1951-52 to 1966-67	1966-67 to 1977-78	1977-78 to 1984-85	1984-85 to 1990-91	1951-52 to 1990-91
		Group I			
Muzaffarnagar	2.58*	4.52*	1.93*	-1.52	4.02*
Meerut	1.85*	3.29*	2.08*	0.56	2.69*
Bulandshahr	1.20*	3.26*	2.13*	-0.92	2.57*
Aligarh	1.25	3.11*	2.33*	1.13**	2.87*
Mainpuri	0.27	3.59*	2.54*	3.80*	3.50*
		Group II			
Saharanpur	4.31*	7.70*	2.80*	-2.88**	6.15*
Mathura	1.14	8.16*	4.44	2.90**	6.39*
Agra	0.95	7.73*	1.85*	3.13*	5.39*
Etah	1.40**	4.29*	3.46*	2.80*	3.56*
Farrukhabad	2.07**	4.61*	2.65*	2.63*	4.23*
Etawah	3.50*	5.35*	-0.42	4.88**	5.46*
		Group III			
Moradabad	4.30*	4.95*	3.72*	-2.27	4.21*
Rampur	7.59*	11.69*	9.91*	2.42	10.32*
Bijnor	4.57*	6.82*	3.08*	1.64**	6.95*
Bareilly	9.69*	10.76*	4.52*	3.48*	9.92*
Budaun	2.50**	5.80*	1.64	1.08	4.12*
Shahjahanpur	2.58*	15.06*	5.45*	3.65**	4.02*
Pilibhit	6.81**	22.21*	8.03*	-1.82	16.87*
Western U. P.	2.27*	5.53*	3.05*	1.06**	4.44*
Uttar Pradesh	0.98*	4.03*	3.86*	1.53*	3.39*

* and ** indicate significant at 1% and 5% level respectively.

Saharanpur district of Group II, and Moradabad and Pilibhit districts of Group III had a negative growth in the groundwater irrigated area. This is attributed tothe fact that net sown area in Uttar Pradesh declined during late seventies and eighties. It declined from 174.21 lakh ha in 1977-78 to 172.89 lakh ha in 1981-82, and is hovering around 172 lakh ha since then. This is the situation in the districts of western region, having negative growth rate in groundwater irrigated area, where culturable land is being diverted for urban and industrial uses.

A split-up of area irrigated by groundwater into tubewell and other wells showed almost a similar trend for tubewell irrigated area in the western region. The area irrigated by other wells depicted declining or negative trend during the study period (Figure 5.1.2). The growth in tubewell irrigated area was higher for the state than that of western region during study period (Table 5.1.5). A negative growth in the other wells irrigated area was observable for the state as a whole during the study periods (Table 5.1.6). Such negative growth rates were observable for western U.P. too, except the period of pre-green revolution.

The growth in net irrigated area by tubewell was higher during the period of early-green revolution for all districts of western region except Mathura, Agra and Etawah of group II. They had higher growth during the period of pre-green revolution. It is attributed to the fact that the consolidation of holdings in early sixties started the process of change and farmers started thinking for assured irrigation facilities. Secondly, there was severe drought during 1965-1967 and a relief measure, state government came in with liberal loan policies and provided electric connections to the farmers on easy terms.

Group-wise comparison showed that decline in well irrigated area had set in the irrigationally more developed districts of group-I as early as in

Table 5.1.5 Compound growth rates(%) of net irrigated area by tubewell development in Western Uttar Pradesh

Districts	1951-52 to 1966-67	1966-67 to 1977-78	1977-78 to 1984-85	1984-85 to 1990-91	1951-52 to 1990-91
		Group I			
Muzaffarnagar	6.34*	7.58*	2.42*	-1.26	7.21*
Meerut	4.94*	7.51*	2.89*	0.42	6.02*
Bulandshahr	3.52*	8.55*	2.90*	-1.01	6.47*
Aligarh	4.04*	8.82*	3.16*	1.41*	7.02*
Mainpuri	11.81*	13.75*	4.64*	4.39*	11.86*
		Group II			
Saharanpur	11.30*	13.40*	3.49*	-2.69**	11.19*
Mathura	38.83*	17.79*	4.79*	2.97**	27.63*
Agra	44.97*	17.86*	2.42*	3.40*	22.89*
Etah	5.09*	12.12*	7.24*	5.88*	8.76*
Farrukhabad	7.13*	10.66*	4.15*	3.72*	9.13*
Etawah	19.88*	18.02*	2.06**	7.28**	22.05*
		Group III			
Moradabad	1.97*	8.53*	9.87*	-0.83	5.59*
Rampur	6.72*	10.08*	14.43*	4.93	10.52*
Bijnor	3.93*	7.70*	3.12*	1.24**	7.25*
Bareilly	6.02*	17.00*	5.81*	8.67*	11.08*
Budaun	0.13	6.99*	2.46	8.82*	4.68*
Shahjahanpur	4.93*	21.07*	6.29*	4.14**	13.22*
Pilibhit	4.77	27.17*	5.89*	-2.40	18.91*
Western U. P.	4.27*	10.68*	4.36*	2.11*	7.96*
Uttar Pradesh	6.46*	11.45*	5.51*	2.31*	9.40*

* and ** indicate significant at 1% and 5% level respectively.

Table 5.1.6 Compound growth rates(%) of irrigated area by other wells in Western Uttar Pradesh

Districts	1951-52 to 1966-67	1966-67 to 1977-78	1977-78 to 1984-85	1984-85 to 1990-91	1951-52 to 1990-91
		Group I			
Muzaffarnagar	-1.02*	-10.45*	-11.92**	-17.46	-8.06*
Meerut	-0.58**	-10.57*	-17.67*	-7.70	-8.60*
Bulandshahr	-0.25	-10.81*	-9.50	-4.13	-7.17*
Aligarh	-0.30	-11.76*	-12.27*	-16.36	-9.79*
Mainpuri	-1.54	-9.76*	-17.28*	-30.44*	-8.78*
		Group II			
Saharanpur	0.63	-11.25*	-21.52**	-37.07*	-10.37*
Mathura	-0.57	-17.43*	-10.92*	-15.69	-10.22*
Agra	-0.79	-13.50*	-9.32**	-8.01**	-6.97*
Etah	0.36	-2.53**	-5.43*	-19.20*	-2.40*
Farrukhabad	0.15	-5.54*	-7.61*	-17.33*	-4.37*
Etawah	2.85*	-3.63**	-8.11*	-15.51*	-2.00*
		Group III			
Moradabad	6.91*	1.21	-9.71*	-12.26	0.45
Rampur	9.31*	14.77*	0.54	-12.23*	9.01*
Bijnor	6.75**	3.02**	2.64	4.64	5.19*
Bareilly	13.82*	5.02*	2.09	-16.73*	7.32*
Budaun	5.44*	4.60*	0.61	-21.19*	2.69*
Shahjahanpur	7.97*	2.28	-0.52	-1.90	4.61*
Pilibhit	8.92*	-2.73	36.70**	3.39	10.30*
Western U. P.	1.03*	-4.02*	-4.54*	-11.06*	-2.54*
Uttar Pradesh	-0.56	-5.21*	-0.39	-7.65*	-4.60*

* and ** indicate significant at 1% and 5% level respectively.

1951-52 while it set in for the Group-II districts from the early green revolution period. The Moradabad and Shajahanpur districts belonging to Group-III experienced this phenomenon during the late seventies, while the rest of the districts of this group in the late eighties. It is evident from the above analysis that with greater development of tubewell irrigation, farmers abandoned irrigation by other wells which is a time and labour consuming source of irrigation and some wells were converted into tubewells. Resource poor small farmers were also compelled to abandon the traditional wells due to the lowering of water table because of higher extraction of groundwater by tubewells.

Based on the above results, the following points emerged. Higher growth in irrigation development was observed during the period of early green revolution. It was an outcome of technological breakthrough in agriculture which made farmers in particular to realise the importance of irrigation and invest more for groundwater irrigation development. Growth in groundwater irrigation development was more than that of canal irrigation in the western region since the 1950s. The trend was similar for the state as a whole except that during the pre-green revolution period, where the growth in canal irrigation was higher than that of groundwater. The growth rate of canal irrigation was higher in all the periods for state as a whole than that of western region. This highlighted the differences in investment pattern in irrigation development during the different phases of agricultural development. The farmers in general have greater preference to tubewell as a source of irrigation than that of canal and other wells due to better reliability and higher efficiency. Thus they have gone for higher investment in the development of this source of irrigation. The analysis also inferred that inter-district equity in the groundwater development improved substantially over the period of time in the western region. It was achieved particularly through higher private investment in the underdeveloped districts where irrigation infrastructure in the year 1951-52 was poor.

5.2 Structure and determinants of groundwater markets

The general information and characteristics of the sample farms, structure of groundwater markets and their determinants have been analysed and presented under three separate heads below.

5.2.1 General information and characteristics of sample farms

Physical and economic aspects of farms such as size of holdings and number of fragments, irrigated area, family composition, land tenurial arrangements, maintenance of water extraction mechanism (WEM) and tractors, and level of fixed investment on farms under different forms of water market were analysed to provide the background information regarding the decision making pattern of farm households under study.

5.2.1.1 Farm size and family composition

The average farm size, irrigated area, family composition and educational status of the head of the family varied widely across the size of farm households. Of the total 180 households, about 20 per cent were marginal (less than 1 ha), 41 per cent were small (1 to 2 ha) and 39 per cent were other categories of farmers (greater than 2 ha) occupying nearly 7, 27 and 66 per cent of the total cultivated area, respectively. The average size of farm was 0.75 ha for marginal, 1.45 ha for small and 3.58 ha for other categories of farms with an overall average size of 2.15 ha (Table 5.2.1.1). In other words, about 61 per cent of farmers commanded only 34 per cent of total cultivated area while remaining

Table 5.2.1.1 Average farm size, irrigated area and family composition of sample farms

Particulars	Marginal	Small	Others	Total
Number of farmers	36 (20.00)[a]	73 (40.56)[a]	71 (39.44)[a]	180 (100)[a]
Total operational area (ha)	27.00 (6.97)[a]	106.16 (27.40)[a]	254.32 (65.63)[a]	387.48 (100)[a]
Average size of holding (ha)	0.75	1.45	3.58	2.15
Irrigated area (ha)	26.72 (98.96)[b]	104.36 (98.30)[b]	254.10 (99.91)[b]	385.18 (99.41)[b]
Average size of family (No)	7.6	7.9	12.6	9.7
Number of family worker	79.50 (29.01)[c]	185.45 (32.30)[c]	246.05 (27.43)[c]	511.00 (29.28)[c]
Family worker per hectare	2.93	1.79	0.98	1.35
Average age of the head of the family	47.00	51.81	57.86	51.90

Notes: Figures in parentheses indicate 'a' percentage to the total farms/area , 'b' percentage of irrigated area to total operational area and 'c' percentage of family worker to size of the family.

39 per cent occupied almost 66 per cent of the cultivated area. This clearly indicates that agrarian structure is dominated by small farm households and distribution of land was uneven among the different categories of farms. Nearly 99 per cent area of the sample farms was reported to be irrigated, indicating well developed irrigation infrastructure.

The examination of family composition revealed that size of family increased with the size of farm, though the difference was only marginal between the marginal and small categories. The overall family size was 9.7 persons. The number of family worker equivalent also increased with the increase in size of the farm, showing a direct relationship with the size of farms. On the contrary, the family workers per unit of land showed an inverse relationship with the farm size. The family workers per hectare worked out to 2.93, 1.79 and 0.98 for marginal, small and other category of farms, respectively with an overall average of 1.35 worker. It showed that the family workers per hectare of land were almost double on marginal farms as compared to the small farms and thrice that of larger farms, indicating prevalence of under employment/disguised unemployment on marginal farms. The average age of the head of the family increased with the farm size. This could be probably due to many young farmers who got seperated from their parents and started cultivation with smaller size of holdings.

5.2.1.2 Maintenance of water extraction mechanism and tractor

The pattern of water extraction mechanism (WEM) and tractor maintained, and area commanded by each WEM and tractor on different categories of farms were examined and the results are presented in Table 5.2.1.2. A total number of 124 WEMs and 48 tractors of different horse power (hp) were maintained by the farm households commanding on an average of 3.11 and 7.99 ha of cultivated land per WEM and per tractor, respectively. Of the total, nearly 69 per cent of WEMs and 87 per cent of tractors were maintained by the other category of farmers who constituted less than 40 per cent of the total farms. The marginal and small category of farmers who constituted more than 60 per cent

Table 5.2.1.2 Maintenance of water extraction mechanisms (WEMs) and tractor across the farm size, sample farms

Farm category	WEM		Tractor	
	Number	Area/WEM (ha)	Number	area/tractor (ha)
Marginal	7	4.09 (5)	1	27.0 (2)
Small	32	3.29 (26)	5	19.92 (11)
Others	86	2.97 (69)	42	6.03 (87)
Total	125	3.11 (100)	48	7.99 (100)

Figures in parentheses indicate percentage to respective total.

of the total number of households owned only 31 per cent of total WEMs and 13 per cent of tractors. This clearly shows the better resource endowment of the large farmers. The operated area per tractor was found to vary widely on different categories of farms. It was nearly 3 hectare per WEM and 6 ha per tractor on the other category of farms to over 4 ha per WEM and 27 ha per tractor for the marginal farms. In other words, this means that large category of farmers had surplus services of their two important farm resources on which the marginal and small farmers were dependent to a greater extent. This gave a lead to custom hiring of tractors and groundwater markets through the existing WEM resource in the study area.

5.2.1.3 Number of holdings and extent of their fragmentation

A study of the number and size of holdings and extent of their fragmentation under different forms of water market are of considerable importance that will throw some light on the WEM installation pattern. A perusal of Table 5.2.1.3 revealed that of the total farm holdings, purely buyers constituted the largest segment (26 per cent) followed by owners+buyers+sellers (23 per cent), owners+ sellers (19 per cent), purely owners (18 per cent) and owners+buyers (14 per cent). In other words, a large proportion (82 per cent) of the total farm households were entering in water markets either fully or partly. Purely owners were out of the markets who constituted merely 18 per cent of the total farm holdings. The sellers and buyers were 42 and 63 per cent of the total farm households, respectively.

The size-wise analysis of buying and selling activities showed that seventy two per cent of the marginal farmers involved in buying of groundwater, while 22 per cent indulged in selling activity. The corresponding figures were 67 and 30 per cent for the small farmers, and 54 and 55 per cent for the large category. It explicitly illustrated that the number of groundwater buyers decreased as the size of farm increased, while the number of sellers increased with the size of farm.

The overall size of the holding in the study area was 2.15 ha with 2.41 fragments per holding. The average size of holding was highest under owners+buyers+sellers (2.67 ha) and lowest under purely buyers (1.30 ha). Similarly, the number of fragments per holding was also highest under owners+buyers+sellers (3.07), but it was lowest under the purely owners form (1.31). This explained the behaviour of farmers installing WEM on big parcel of

Table 5.2.1.3 **Distribution of farm holdings, operational size and fragments per farm across various forms of water market**

Farm Category	Purely Buyers	Owners+ buyers	Owners+ buyers+sellers	Owners+ sellers	Purely owners	Total
			Number of farm holdings			
Marginal	19	4	3	5	5	36
	(53)	(11)	(8)	(14)	(14)	(100)
Small	20	13	16	13	11	73
	(27)	(18)	(22)	(18)	(15)	(100)
Others	7	9	22	17	16	71
	(10)	(13)	(31)	(24)	(22)	(100)
Total	46	26	41	35	32	180
	(26)	(14)	(23)	(19)	(18)	(100)
			Size of farm holdings in hectare			
Marginal	0.74	0.66	0.64	0.87	0.79	0.75
Small	1.36	1.42	1.50	1.51	1.54	1.45
Others	2.63	3.82	3.79	3.44	3.73	3.58
Total	1.30	2.14	2.67	2.35	2.52	2.15
			Number of fragments per holding			
Marginal	2.26	2.00	2.00	1.40	1.00	1.92
Small	2.35	3.08	3.00	1.69	1.00	2.30
Others	3.00	3.11	3.27	2.88	1.63	2.76
Total	2.41	2.92	3.07	2.23	1.31	2.41

Figures in parentheses indicate percentages to respective total.

land to irrigate their crops and sell the surplus water after meeting own requirement. However, they had to rely on buying water from neighbouring farmers for the other fragments which were situated away from their own WEM. The lower size of holding acted against certain farmers installing their own WEM due to high overhead costs inconsistent with the size of operational holding. This resulted in the purely buyers category of farmers with more fragmented holdings resorting exclusively to buying. The lower level of fragmentation under the purely owners form of water markets placed them at an advantage of selecting the suitable WEM with break even overheads so that the whole extracted water is utilised for irrigating their own crops. Hence, they did not undertake the selling activity. This could explain the variations in the buying and selling activities in the water markets by the farmers of various size groups.

5.2.1.4 Capital investment pattern

The study of fixed capital investment pattern of farmers under different forms of water market is of importance in understanding the capital availability of the farmers and its composition. Land, farm building, farm machinery and equipments, irrigation infrastructure and livestock constituted the major items of capital investments made. A comparative picture of per hectare and per farm value of fixed assets under different forms of water market is shown in Table 5.2.1.4. Inclusion of land would have made the comparison less sensitive with respect to the rest of the assets and hence it was excluded. Similarly, residential houses were also excluded from the fixed investment. Since per farm figures give the financial position of farm households and per hectare make the comparison sharp, the estimates were made accordingly.

Table 5.2.1.4 Fixed investment on farm building, irrigation infrastructure, farm machinery and equipment under different forms of water market

('000 rupees)

Particulars	Marginal per farm	Marginal per hectare	Small per farm	Small per hectare	Others per farm	Others per hectare	All per farm	All per hectare
				Farm Building				
Purely buyers	28.3	38.1	35.6	26.3	47.1	17.9	34.3	26.5
Owners+buyers	35.0	53.0	43.4	30.5	55.9	14.6	46.4	21.7
O+B+S*	30.0	46.0	45.6	30.4	53.4	14.1	48.7	18.1
Owners+sellers	38.6	44.3	35.8	23.7	53.1	15.4	44.5	18.9
Purely owners	34.3	43.4	43.0	28.0	57.5	15.4	48.9	19.4
Total	31.5	41.9	40.3	27.7	54.0	15.1	43.4	20.4
				Irrigation Infrastructure				
Purely buyers	0.26	0.35	0.10	0.07	6.07	2.31	1.08	0.83
Owners+buyers	3.50	5.30	9.69	6.80	31.9	8.35	16.4	7.69
O+B+S*	3.33	5.21	11.4	7.57	24.4	6.40	17.7	6.64
Owners+sellers	13.9	15.9	20.5	13.6	29.3	8.52	23.8	10.2
Purely owners	5.70	7.20	19.0	12.4	32.9	8.81	23.9	9.48
Total	3.53	4.70	10.8	7.40	26.6	7.42	15.6	7.22
				Farm Machinery				
Purely buyers	9.50	12.7	13.7	10.1	35.1	13.3	15.2	11.7
Owners+buyers	10.5	15.9	14.6	10.3	87.3	22.9	39.1	18.3
O+B+S*	10.8	16.9	20.6	13.7	65.3	17.2	43.9	16.5
Owners+sellers	15.0	17.1	24.3	16.1	98.6	28.7	59.0	25.1
Purely owners	11.2	14.1	31.6	20.5	91.5	24.5	58.4	23.2
Total	10.7	14.3	20.0	13.7	79.0	22.1	41.4	19.2
				Farm Equipment				
Purely buyers	0.92	1.24	1.30	0.96	1.72	0.65	1.20	0.93
Owners+buyers	1.46	2.22	1.64	1.15	2.38	0.63	1.87	0.87
O+B+S*	1.32	2.06	1.60	1.07	2.43	0.64	2.02	0.76
Owners+sellers	1.51	1.73	1.79	1.19	2.60	0.76	2.14	0.91
Purely owners	1.12	1.41	1.57	1.02	2.57	0.69	2.00	0.80
Total	1.12	1.50	1.55	1.07	2.43	0.68	1.81	0.84
				Total Investment				
Purely buyers	39.0	52.4	50.7	37.4	90.1	34.2	51.8	40.0
Owners+buyers	50.5	76.5	69.3	48.7	177.4	46.5	103.8	48.6
O+B+S*	45.5	71.1	79.2	52.8	145.7	38.4	112.4	42.1
Owners+sellers	69.0	79.1	82.3	54.6	183.5	53.4	129.5	55.1
Purely owners	52.3	66.0	95.1	61.8	184.5	49.5	133.1	52.9
Total	46.8	62.4	72.6	49.9	162.0	45.2	102.7	47.7

* represents owners+buyers+sellers.

The comparison across different categories of farms revealed that capital investment per farm showed an increasing trend with increase in farm size whereas a reverse trend was observed in capital investment per unit of land in all forms of water market. The total investment per farm was nearly Rs 52 thousands on purely buyers farms and more than double on owners+buyers farms. It further increased on owners+buyers+sellers farms, followed by owners+sellers and purely owners. Per hectare investment was also lower on purely buyers farms and highest on owners+sellers farms, though the differences among the different forms of water market were less. Investment per hectare on owners+buyers+sellers farms was marginally higher than purely buyers, eventhough per farm investment was more than double corresponding to the size of holding.

Comparing the share of different components of the fixed investment among the different forms of water market, it was observed that the major item of investment was on farm building (66 per cent) followed by farm machinery (29 per cent) on purely buyers' farms. Investment on irrigation infrastructure was very low on buyers' farm. However, the investment pattern showed a decline in the share of farm building (44 per cent) and an increase in share for farm machinery and irrigation infrastructure (38 and 16 per cent) in the case of owners+buyers and owners+buyers+sellers, respectively. On the contrary, farm machinery ranked first (45 per cent) followed by investment on farm building (35 per cent) and irrigation infrastructure (18 per cent) on purely owners and owners+sellers. The investment share on farm implements was lowest (2 per cent) for almost all forms of water market.

The results indicated that capital investment per farm was showing an inverse relationship with farm size, while a direct relationship was observed for capital investment per hectare under all forms of water market. While the variation in the total investment per farm was very high, the variation in investment per hectare was low among water markets. High investment share was made on farm buildings by buyers category (purely buyers, owners+buyers and owners +buyers +sellers), whereas investment share made by owners category (owners+sellers and purely owners) was more on farm machinery. Variation in the investment in irrigation infrastructure was modest among the various forms of water market except that in the case of purely buyers.

5.2.1.5 Land tenancy and its magnitude

Ownership rights of farmers is a major factor which influences the nature of production, production practices, adoption of modern technology and capital investment on farms. Farmers are the owners of their land after permanent settlement of land in Uttar Pradesh, eventhough some entered in land market activities on a limited scale. It is apparent from the Table 5.2.1.5 that of total, 23 farmers indulged in land markets in form of leasing in and leasing out of land, constituting nearly 4 per cent of the total sample under study. The owned land occupied by farmers formed 99 per cent of the total area. Farmers under purely owners category did not indulge in any type of land markets activities. Nine farmers from owners+sellers category indulged in leasing in activity representing 4 per cent of area. Land tenancy was low among owners+buyers+sellers, owners+ buyers and purely buyers also.

Table 5.2.1.5 Land tenancy under different forms of water market across the farm size, sample farms

Particulars	Farmers entered in land market		% of area under land tenancy		% of owned area to total area
	leased in	leased out	leased in	leased out	
Marginal					
Purely buyers	-	-	-	-	100
Owners+buyers	-	-	-	-	100
Owners+buyers+sellers	-	-	-	-	100
Owners+sellers	2	-	19.78	-	83.49
Purely owners	-	-	-	-	100
Total	2	-	2.74	-	97.33
Small					
Purely buyers	1	-	2.22	-	97.79
Owners+buyers	2	-	7.93	-	92.66
Owners+buyers+sellers	4	2	9.48	7.79	98.33
Owners+sellers	3	-	5.72	-	94.59
Purely owners	-	-	-	-	100
Total	10	2	5.72	1.79	96.78
Others					
Purely buyers	-	-	-	-	100
Owners+buyers	-	-	-	-	100
Owners+buyers+sellers	3	1	2.93	2.88	99.95
Owners+sellers	4	1	2.81	0.35	97.60
Purely owners	-	-	-	-	100
Total	7	2	1.6	1.03	99.43
All					
Purely buyers	1	-	1.02	-	98.99
Owners+buyers	2	-	2.51	-	97.55
Owners+buyers+sellers	7	1	4.3	3.89	99.60
Owners+sellers	9	3	4.27	0.25	96.14
Purely owners	-	-	-	-	100
Total	19	4	2.62	1.16	98.56

The foregoing analysis clearly established that land market activities were not in vogue in the study area, and only a handful of owners+sellers and owners+buyers +sellers categories of farmers were involved in leasing in activity on a very limited scale. These farmers by virtue of having surplus irrigation facilities were participating in the leasing in activity to harness the maximum advantage of groundwater resource availability.

5.2.2 Structure of groundwater markets

Buying and selling of groundwater is primarily influenced by the nature and magnitude of agricultural development, distribution of resources and socio-economic status of the farmers. It may be recalled that most of the small and marginal farmers were dependent on the large farmers, who had surplus groundwater, to irrigate their fields. Large farmers with more fragmented holdings were also water buyers. Hence, the accessibility of farmers and their land to different forms of water market and water extraction mechanisms (WEMs), area irrigated by own WEM, and buying and selling of groundwater are analysed and presented in this section.

5.2.2.1 Accessibility to water extraction mechanisms (WEMs)

Of the total, as high as 66 per cent sample households had access to electric operated WEMs alone, while the remaining 34 per cent households were using partially or fully diesel operated WEMs (Table 5.2.2.1). However, the prevalence of purely diesel operated WEMs was modest and accounted for only 2 per cent accessibility to sample households.

The examination of accessibility across the farm size revealed that 78 per cent of marginal farmers had access to electric operated WEMs, while the

Table 5.2.2.1 Accessibility of farmers and their area to different water extraction mechanisms (WEMs)

WEMs	Marginal	Small	Others	Total
	Number of farmers			
Electric operated	28 (78)	47 (65)	44 (62)	119 (66)
Diesel Operated	- (0)	1 (1)	3 (4)	4 (2)
Electric+diesel operated	8 (22)	25 (34)	24 (34)	57 (32)
Total	36 (100)	73 (100)	71 (100)	180 (100)
	Area in hectare			
Electric operated	23.80 (89)	81.82 (78)	193.44 (76)	299.06 (78)
Diesel operated	1.92 (7)	15.34 (15)	36.88 (15)	54.14 (14)
Electric+diesel operated	1.00 (4)	7.20 (7)	23.78 (9)	31.98 (8)
Total	26.72 (100)	104.36 (100)	254.10 (100)	385.18 (100)

Figures in parentheses indicate percentage to total.

remaining 22 per cent had access to electric plus diesel operated WEMs. However, none of the marginal farmer had access to only diesel operated WEMs. The corresponding figures for electric and electric plus diesel WEMS were 65 and 34 per cent for the small farmers and 62 and 34 per cent for the other category, respectively. Only one per cent of the small farmers and 4 per cent of other category farmers had access to diesel operated WEMs. Thus, while the access to electric and electric plus diesel operated WEMs varied widely, such pronounced variation was not much for diesel operated WEMs.

While comparing the accessibility of irrigated land to different types of WEMs, it was observed that of the total irrigated area, 78 per cent had access to electric operated WEMs, 14 per cent to diesel and 8 per cent to electric plus diesel operated WEMs. The same trend was observed in all the categories of farms, showing thereby the popularity of electric operated WEMs in the area. It may further be noted that only 2 per cent farmers had access to purely diesel operated WEMs, but provided accessibility to 14 per cent of irrigated land. It was due to the fact that substantial parcel of land had no accessibility to electric operated WEMs, had totally dependent on diesel operated WEMs. On the other hand, 32 per cent farmers had access to electric plus diesel operated WEMs, but only 8 per cent of the total irrigated land had accessibility to by this mode of WEMs. However, a small fraction of farmers but owning larger sized farms particularly small and other category of farmers had preferred to keep their options open for both the means, electricity as well as diesel operated WEMs. This in turn increased the possibility of water availability during the poor supply of electricity or breakdowns of electricity operated WEMs particularly at the critical stages of crop growth. However, these farmers preferred to irrigate their land by electric operated WEMs purely on cost consideration until unless they were forced by circumstances. Due to this fact, the accessibility of farmers' land to electric cum diesel operated WEMs appeared to be much less than that of accessibility of number of farmers.

It is concluded from the above analysis that accessibility of the farmers and their land to electric operated WEM has inverse relationship with farm size, and direct relationship with purely diesel and electric plus diesel operated WEMs. Though farmers had accessibility to both types of WEMs, there had been a marked preference for electric operated WEMs, purely on cost consideration.

5.2.2.2 Accessibility to water markets

Accessibility of farmers' land to different forms of water market have been examined in detail and results are presented in the Table 5.2.2.2. It is evident that the accessibility of farmers and their cultivated land to different forms of water market gave a mixed picture. While, 23 per cent of the sample farmers had accessibility to owners+buyers+sellers form of water markets (Table 5.2.1.3). The accessibility of farmers' land to this type of water markets was reported to be as high as 28 per cent of the total irrigated land under study. On the contrary, 26 per cent of the farmers falling under purely buyers type of water markets accounted only 16 per cent of the total irrigated land under this form of water markets.

A category wise comparison showed that the number of marginal and small farmers had almost proportionate accessibility of their land to all forms of water market. Almost a similar pattern was observed for the other category of farmers, except that in case of purely buyers and owners+buyers+sellers form of water markets. Nearly 10 per cent farmers of other category under purely buyers had only 7 per cent accessibility to land of this category, while 31 per cent farmers under owners+buyers+sellers had accessibility to 33 per cent of the total land under this category.

Table 5.2.2.2 Accessibility of farmers' area to different forms of water market

(Area in ha)

Water markets	Marginal	Small	Others	Total
Purely buyers	13.84	26.88	18.44	59.16
	(52)	(26)	(7)	(16)
Owners+buyers	2.64	18.32	34.14	55.10
	(10)	(18)	(14)	(14)
Owners+buyers+sellers	1.92	23.78	83.44	109.14
	(7)	(23)	(33)	(28)
Owners+sellers	4.36	19.34	58.40	82.10
	(16)	(18)	(23)	(21)
Purely owners	3.96	16.04	59.68	79.68
	(15)	(15)	(23)	(21)
Total	26.72	104.36	254.10	385.18
	(100)	(100)	(100)	(100)

Figures in parentheses indicate percentage to total.

It is concluded from the foregoing discussion that the accessibility of farmers and their land to water markets have inverse relationship with farm size for purely buyers and direct relationship for almost all other forms of water market. No marked difference in access of farmers and their area to various forms of water market was observed in marginal and small categories of farms. However, in case of other category of farms, no single trend was observed. This is understandable when viewed against the fact that purely buyers have comparatively small operational holdings who failed to install their own WEMs and forced to enter in water buying activity.

5.2.2.3 Accessibility to WEMs under different water markets

Magnitude of accessibility of farmers and their land to various WEMs under different forms of water market have been analysed separately and results are presented in Table 5.2.2.3. The results clearly indicated that higher proportion of farmers and their area had access to electric operated WEMs under all forms of water market. The proportion of the latter was higher than the former. The farmers under purely buyers, owners+buyers, owners+buyers +sellers (buyers category) had proportionately higher accessibility to electric plus diesel operated WEMs and lesser to electric operated WEMs than those of owners+sellers and purely owners (owners category) of water markets. The greater diversification in WEMs under buyers category of farms may be due to their fragmented holdings. However, there were few farmers who were forced to depend on purely diesel operated WEMs on account of unwarranted exigencies and such farmers fall under owners+sellers form of water markets. The area irrigated by this means of WEMs accounted from 6 per cent under purely owners to 19 per cent under owners+sellers. In contrast to the number of farmers, the coverage of area having access to electric cum diesel operated WEMs was quite lower under all forms of water market. The above findings thus explained that the fragmentation of holdings which compelled farmers to depend on diesel operated WEMs for irrigating some parcel of land having no access to electric WEMs and/or diesel operated WEMs were used only at the time of breakdown/shortage of electric supply during critical periods of crops. This is in consonance with the findings of Table 5.2.2.1, where the accessibility of farm size with respect to different types of WEMs were analysed.

Table 5.2.2.3 Magnitude of accessibility of farmers and their area to different water extraction mechanisms across the forms of water market

Water markets	Electric operated	Diesel operated	Electric+diesel operated	Total
		Numbers of farmers		
Purely buyers	30 (65)	- (0)	16 (35)	46 (100)
Owners+buyers	16 (62)	- (0)	10 (38)	26 (100)
Owners+buyers+selles	21 (51)	- (0)	20 (49)	41 (100)
Owners+sellers	25 (72)	4 (11)	6 (17)	35 (100)
Purely owners	27 (84)	- (0)	5 (16)	32 (100)
Total	119 (66)	4 (2)	57 (32)	180 (100)
		Area (hectare)		
Purely buyers	45.12 (76)	7.24 (12)	6.80 (12)	59.16 (100)
Owners+buyers	44.16 (80)	7.52 (14)	3.42 (6)	55.10 (100)
Owners+buyers+sellers	78.00 (71)	19.22 (18)	11.92 (11)	109.14 (100)
Owners+sellers	63.06 (77)	15.84 (19)	3.20 (4)	82.10 (100)
Purely owners	68.72 (86)	4.32 (6)	6.64 (8)	79.68 (100)
Total	299.06 (78)	54.14 (14)	31.98 (8)	385.18 (100)

Figures in parentheses indicate percentage to the total.

It is concluded from the above analysis that accessibility of number of farmers and their land to electric operated WEMs was very high. Buyers category had higher accessibility to electric plus diesel operated WEMs than that of owners category of water markets. The accessibility of farmers' land was considerably lower than that of their number to electric plus diesel operated WEMs. The existence of Diesel operated WEMs was very limited, even then, farmers' land under all the forms of water market accessed them.

5.2.2.4 Dynamics of water buying and selling

The area irrigated by own sources, buying and selling activities and their magnitude were analysed and results are presented in Table 5.2.2.4. The purely buyers, and purely owners and owners+sellers had cent per cent of their land irrigated by water buying and by own sources, respectively. On an average, of the total irrigated area under study, nearly three fourth was commanded by own WEMs, while remaining one fourth by buying groundwater, implying thereby that in the absence of groundwater markets, over one-fourth land in the study area would have remained unirrigated. The marginal farmers irrigated nearly 57 per cent of their cultivated area by buying water from the groundwater markets. However, the water buying was relatively low in case of small and other categories of farmers (41 and 16 percentages respectively), illustrating differences in the water buying dynamics among the farm size groups. Such differences were more visible across various forms of water market.

WEM owners who had surplus water after meeting their requirements, sold the same to other needy farmers for irrigating their land. On an average, the sale of surplus water commanded other farmers' land up to the

Table 5.2.2.4 Distribution of area irrigated by own WEMs, and by buying and selling under different forms of water market

Water markets	Percentage of own area irrigated by		Per cent area irrigated by buying water from same category of farmers
	own WEM	buying	
Marginal			
Purely buyers	-	100.00	-
Owners+buyers	66.67	33.33	-
Owners+buyers+sellers	75.00	25.00	61.11
Owners+sellers	100.00	-	54.13
Purely owners	100.00	-	-
Total	43.11	56.89	28.13
Small			
Purely buyers	-	100.00	-
Owners+buyers	64.19	35.81	-
Owners+buyers+sellers	60.89	39.11	53.31
Owners+sellers	100.00	-	64.53
Purely owners	100.00	-	-
Total	59.05	40.95	32.78
Others			
Purely buyers	-	100.00	-
Owners+buyers	82.72	17.28	-
Owners+buyers+sellers	80.49	19.51	42.76
Owners+sellers	100.00	-	30.29
Purely owners	100.00	-	-
Total	84.01	15.99	21.92
All			
Purely buyers	-	100.00	-
Owners+buyers	75.79	24.21	-
Owners+buyers+sellers	76.12	23.88	44.92
Owners+sellers	100.00	-	39.61
Purely owners	100.00	-	-
Total	74.41	25.59	24.51

extent of nearly 25 per cent of their owned irrigated land. However, the extent of selling of groundwater was higher on owners+buyers+sellers farms than that of owners+sellers.

5.2.3 Determinants of groundwater markets

The groundwater markets have significant effect on the exploitation of groundwater resources, pattern of groundwater use and allocation of energy resources to the agriculture sector. The structural framework of groundwater markets has been examined in the previous section. An attempt has been made in this section to examine the determinants of groundwater markets. Development and working of these markets depend upon many agro-climatic and socio-economic factors, farm characteristics and technology, and farmer's managerial ability. The relative significance of these important factors were quantified by logistic regression analysis for WEM ownership, water buying and selling decision of the farmers. The factors considered to influence the groundwater markets more apparently are only included in the logit analysis and they are size of holding, number of farm fragments, use of electricity (i.e. cheap source of energy), proportionate area under sugarcane (i.e.high value cash crop), installed horse power (hp) per hectare, years of schooling of head of the family, proportion of family workers to total family, proportion of non-farm income to total income, water charge and joint ownership of WEM. Total value of farm assets, cropping intensity and age of head of the family were also included in the analysis, but due to high degree of correlation between farm size and farm assets, area under sugarcane and cropping intensity, and educational level and age of the head of the family, were subsequently dropped in the final model.

The determinants of groundwater markets for WEM owners, water buyers and sellers have been examined separately to visualise the differences, if any. Similarly, the sources of energy used to operate the WEM were also taken into consideration while examining the determinants.

5.2.3.1 Ownership of WEM

Installation of a WEM is very important in modern agriculture as it is considered to be most reliable, adequate and flexible irrigation source of modern agriculture. Electricity and diesel are the two main sources of energy to operate a modern WEM and factors which affect the ownership of these WEMs are also different, thus necessitating their examination separately.

5.2.3.1.1 Electric operated WEM

The important variables selected and maximum likelihood estimates of the coefficients of logistic regression analysis are reported in Table 5.2.3.1. The model fits very well to the data as indicated by large observed significance of log likelihood ratio test , and chi-square test which was significant at one per cent level. The model provided 83 per cent correct prediction of the dependent variable.

The variables having significant effect on farmers' decision on the ownership of an electric operated WEM were size of owned operational holding, number of farm fragments and joint ownership at the time of installation of WEM. Size of holding is a significant variable having the expected positive sign, implying that farmers with large operational holding were more likely to own a WEM than a farmer with small operational holding. The number of farm fragments was another significant factor having expected negative sign, implying

Table 5.2.3.1 **Logistic regression coefficients of factors affecting the installation of an electric operated water extraction mechanism**

Factors	Coefficient	T-value	Mean
Intercept	-1.1551	-0.7127	1.00
Number of fragments per farm	-0.6685*	-2.6308	2.41
Owned operational area (ha)	1.3047*	4.1728	2.12
Cheap source of energy (electricity)	-0.0791	-0.1265	0.66
Per cent of gross cropped area under sugarcane	0.0211	0.9985	50.88
Number of year of schooling	0.0437	0.8763	5.63
Percentage of family worker to family	-0.0059	-0.2633	33.29
Percentage of non-farm income to total income	-0.0141	-1.1985	21.95
Joint ownership at the time of installation	6.8387*	4.1552	0.33
-2 Log Likelihood	114.77		
Chi-Square	89.83*		
Correct prediction (%)	83.33		
Number of observations	180		

* indicates significant at 1% level.

thereby that higher fragmentation inhibited tubewell ownership. The sign and magnitude of the coefficient of joint ownership at the time of installation indicated that joint-ownership gave an opportunity to make higher investment in WEM by pooling financial resources. It also gave an opportunity to higher capacity utilization of a WEM by increasing the command area of a WEM through collective efforts. Electricity, though a cheap source of energy did not have any significant effect. Same was the case with percentage of gross cropped area under sugarcane, level of education (year of schooling of the head of the family), percentage of farm family workers to family size and non-farm income to total income on the probability of ownership of a WEM.

The perception about the ownership of an electric operated WEM were also examined and the results are presented in Table 5.2.3.2. The large size of operational holdings, joint ownership, higher number of farm fragments, non-availability of canal water, adoption of new technology, low WEM density, availability of institutional credit, subsidised interest rate of institutional credit, higher non-farm income were identified as possible important factors to be considered for the ownership of an electric operated WEM. Ownership of WEMs was a symbol of social status in the Western UP, and hence this was also included as a possible important factor contributing to the decision to own an electric operated WEM.

More than one fourth of the respondents gave their first choice to large farm size. This choice increased as farm size of respondents increased. More than one fifth farmers responded to joint ownership as their first choice. Substantial higher percentage (47 per cent) of marginal farmers responded to joint ownership than that of small (18 per cent) and others (17 per cent). The main reason for higher response to joint ownership by marginal farmers was due to the high investment needed to install an electric operated WEM which would not be possible individually by a single marginal farmer. Good response were also reported by the farmers of other category to have more than one WEM. More so, nearly one sixth respondents preferred their first choice to larger size of farm

Table 5.2.3.2 Owners' perception about the installation of an electric operated water extraction mechanism

Factors	Percentage of respondent as their first choice			
	Marginal	Small	Others	All/Total
Respondent (number)	17	50	60	127
Large farm size	12	22	33	26
Joint ownership	47	18	17	21
Large size of fragments	6	14	22	17
Non-availablility of canal water	12	14	15	14
Adoption of new technology	11	12	8	10
Lower WEM density	6	10	3	6
Cultivation of high value crops	6	6	2	4
High water table	0	2	0	1
Availability of institutional credit	0	2	0	1

fragments. This preference increased with the increase in size of farm fragments varying from 6 per cent for marginal farmers to 22 per cent for other size of farmers. Another important factor which has been responsible for installation of an electric operated WEM was the increasing non-accessibility to canal water over the years.

The reason for installation of an electric WEM on account of adoption of modern technology was indicated by 10 per cent of the respondents. Six per cent of the total respondents were reported to install their WEM due to lower WEM density around their farm, leading to poor and or non-availability of purchased water. Four per cent farmers responded to the cultivation of high value crops such as sugarcane. High water table and availability of institutional credit was the first choice for only one per cent farmers who belonged to the small category. Subsidised interest rate, higher non-farm income and WEM ownership as a symbol of social status were found to be non-influencing factors for the ownership of electric operated WEM in the study area.

5.2.3.1.2 Diesel operated WEM

Though electricity is a cheap source of energy to lift groundwater as compared to diesel, some farmers install a diesel operated WEM due to a couple of reasons. The important factors were identified and perceptions of

Table 5.2.3.3 Owners' perception about the installation of diesel operated water extraction mechanism

Factors	Percentage of respondent as their first choice		
	Small	Others	All/Total
Respondent (number)	6	23	29
Larger fragmentation	33	22	24
Non-availablility of canal water	17	17	17
Multiple uses of engine/tractor	17	13	14
Irregular supply of electricity	0	17	14
More control on water	17	9	10
Low cost of installation	0	9	7
Ease in transportation/movement	17	4	7
Difficulties in getting electricity connection	0	5	4
High frequency of breakdown of electricity	0	4	3

Note: Marginal farmers did not have any diesel operated WEMs.

ownership were recorded to quantify the significance of these factor in the installation of diesel operated WEM. A perusal of Table 5.2.3.3 indicated that marginal farmers did not have any diesel operated WEM at all. More than one fourth respondents cited larger fragmentation of their holdings as the first choice to install a diesel operated WEM. The availability of canal water was not a problem till the eighties. However, non-availability of canal water in its tail -end area is a major problem of late. This was considered as one of the most important factors by 17 per cent respondents. Fourteen per cent of the farmers preferred diesel operated WEM because of multiple uses of engine/tractor and irregular supply of electric power separately. Relatively higher control on irrigation water was preferred by 10 per cent of respondents. The low cost of installation and ease in transportation/ movement of the diesel operated WEM were the reason for preferring diesel operated WEM by 7 per cent farmers. Only 4 and 3 per cent respondents considered difficulties in getting electricity connection and high frequency of breakdown of electricity as the first reason for installing a diesel operated WEM respectively. Other factors which were not preferred as influencing factors by a single farmer were high level of water table, low operating cost, high security cost of an electric operated WEM, non-farm income and a symbol of social status.

5.2.3.2 Buying of groundwater

The groundwater markets give an opportunity to non-WEM owners and non-owners of a WEM on a particular parcel of land to irrigate their crops and in raising their productivity. There are several factors which affect groundwater buying decision of the farmers. They were tested by using a logistic regression analysis as water buying is a binary variable. Farmers' perception on buying groundwater were also analysed and discussed separately.

The results obtained from the logistic regression analysis are presented in Table 5.2.3.4. The model provided 79 per cent correct predictions. Large observed significance of log-likelihood ratio test and 1 per cent significance level of chi-square indicated the model fitted very well to the data.

Table 5.2.3.4 Logistic regression coefficients of factors affecting the groundwater buying of farmers

Factors	Coefficient	T-value	Mean
Intercept	1.7904	1.1226	1.00
Number of fragments per farm	1.0995*	4.8437	2.41
Total operational area (ha)	-0.5046*	-3.3861	2.15
Cheap source of energy (electricity)	0.5018	0.8453	0.66
Per cent of gross cropped area under sugarcane	-0.0227	-1.2688	50.88
Number of year of schooling	-0.0910**	-2.2304	5.63
Percentage of family worker to family	-0.0058	-0.2851	33.29
Percentage of non-farm income to total income	-0.0112	-1.0969	21.95
Irrigation price per hour (electric WEM)	-0.0132	-0.0917	6.89
Joint ownership of WEM	-1.4625*	-3.6869	0.47
-2 Log likelihood	180.97		
Chi-Square	56.67*		
Correct Prediction (%)	78.89		
Number of observations	180		

* and ** indicate significant at 1% and 5% level, respectively.

The results clearly indicated that the total operational area, number of fragments per farm, year of schooling of the head of the family and joint ownership of WEM were significant factors which affected the water buying decision of farmers. Sign and magnitude of the coefficients were according to prior expectations. The size of operational holding, years of schooling and joint ownership of WEM had negative sign indicating that as the size of holding, level of education and joint ownership increased, the buying of groundwater decreases. In other words, the buying of groundwater would be favoured by the small sized farmers with low education and low probability of joint ownership to install a WEM. Number of fragments per farm had a positive significant effect on water buying. It is obvious that with more dispersed holdings, farmers would not be able to install many WEM to irrigate their fragmented land but would prefer to purchase water. Electricity as a cheap source of energy, higher fraction of gross cropped area under sugarcane, family worker to total family members, non farm income to total income and higher water price though showed positive effect on buying of groundwater in the study area, but they were non-significant.

Buyers' perception about buying groundwater showed that the major factors which appeared to affect the water buying were the large fragmentation of holdings, non-availability of canal water in the canal command area, non availability of a suitable joint ownership, higher WEM density around their holding, accessibility to state tubewell, number of part-time farmers, non-availability of institutional credit, non-subsidised interest rate of institutional credit, policy of state electricity board to issue the connection, low water purchasing price, high water table, less non-farm income, cultivation of low value crops and high security cost of WEM.

Table 5.2.3.5 **Buyers' perception about the buying of groundwater**

Factors	Percentage of respondent as their first choice			
	Marginal	Small	Others	All/Total
Respondent (number)	26	49	38	113
Larger fragmentation	42	39	68	49
Non-availability of canal water	12	20	11	15
Non-availability of a suitable partner	15	11	13	12
Higher WEM density	12	10	3	8
Small size of holding	15	8	0	7
State tubewell	0	4	3	3
Part-time farmer	4	2	0	2
Non-availability of institutional credit	0	2	0	1
Non-subsidised interest rate	0	2	0	1
Electricity board's policy to issue connection	0	0	2	1
Low water price	0	2	0	1

It is apparent from the Table 5.2.3.5 that nearly half of the respondents were buying water due to larger fragmentation of their holdings. Nearly 40 per cent of the small and marginal and two third of others category of farmers reported to buy the groundwater due to larger farm fragmentation. Non-availability of canal water in its tail-end area was identified as another important factor reported as their first choice by 15 per cent respondents. Lack of suitable joint partnership to install a WEM appeared to be another important factor which was considered by 12 per cent of respondents as their first choice to buy water. Higher WEM density around their holdings was preferred by 8 per cent respondents which varied from 3 per cent for other category to 12 per cent for the marginal farmers. The smaller size of operational holding was considered by the marginal (15 per cent) and small (8 per cent) farmers only as their first choice. Only 3 per cent of small and large category of farmers considered accessibility to state tubewell as their first choice to buy groundwater instead of installation of a WEM. Four per cent of marginal and two per cent of small farmers were part-time farmers, who were also buying water from their neighbours. Non-availability of institutional credit, non-subsidised interest rate of institutional credit, policy of state electricity board of not issuing electricity connections to the WEMs having power requirement less than 7.5 hp in the study blocks, and low water charges were considered as first choice by a few respondents, who accounted only for 1 per cent of the total respondents. The other factors such as level of water table, non-farm income, cultivation of low value crops and high security cost of WEM were found to be non-influencing variables as not a single farmers responded to these factors.

From the above discussion it is concluded that number of farm fragmentation, small size of holding, non-availability of a suitable joint partnership, non-availability of canal water and level of education of the head of the family were the important factors which affected the groundwater buying decision of farmers in the study area.

5.2.3.3 Selling of groundwater

After studying the determinants of ownership of a WEM and groundwater buying of farmers, it is important to study the determinants of

Table 5.2.3.6 **Logistic regression coefficients of factors affecting the groundwater selling of farmers**

Factors	Coefficient	T-value	Mean
Intercept	-3.7824**	-2.1939	1.00
Number of fragments per farm	0.4150**	2.2663	2.41
Owned operational area (ha)	0.3026**	2.0671	2.12
Cheap source of energy (electricity)	-0.1553	-0.2648	0.66
Installed horse power per hectare (electricity)	0.6276*	4.4577	1.79
Per cent of gross cropped area under sugarcane	0.0321	1.5872	50.88
Number of year of schooling	-0.0205	-0.5365	5.63
Percentage of family worker to family	0.0045	0.2201	33.29
Percentage of non-farm income to total income	-0.0043	-0.3820	21.95
Irrigation price per hour (electric WEM)	-0.2320	-1.5601	6.89
Joint ownership of WEM	1.2373*	3.1835	0.47
-2 Log likelihood	184.61		
Chi-Square	60.55*		
Correct Prediction (%)	71.11		
Number of observations	180		

* and ** indicate significant at 1% and 5% level, respectively.

groundwater selling decision of farmers. There are several factors which affect the groundwater selling decision of farmers. The prediction of groundwater selling decision of farmers using logistic regression analysis are presented in

Table 5.2.3.6. The model predicted the selling behaviour with 71 per cent accuracy. Large observed significance level of log likelihood ratio test and one per cent significance level of chi-square indicated that model fitted very well to the data.

The size of owned operational holding, number of farm fragments, horse power (hp) per unit of land and joint ownership of WEM were the significant factors which affected the selling decision of groundwater. The farmers with larger size of operational holding were in a position to install WEM with intention to hire out excess water for additional earnings. This has been made possible as most of the small and marginal farmers have no financial capacity to install their own WEM making them totally dependent on large farmers to irrigate their crops. Probability of selling water bears a direct relationship with farm fragmentation. It could be explained as fragmentation decreased capacity utilization of a WEM on owned land and selling increased the capacity utilization of the same. Higher horse power (hp) per unit of cultivated land have increased the probability of selling water as expected. Joint ownership gave opportunity to install a WEM, therefore it also increased probability of selling of water. Electricity as a cheap source of energy to lift groundwater, proportion of gross cropped area under sugarcane, year of schooling of the head of the family, proportion of family labour to total family were non-significant. Proportion of non-farm income to total income and selling price have expected signs, but they were non-significant. It is concluded from the above discussion that the size of owned operational holding, number of farm fragments, installed horse power (hp) per ha and joint ownership of WEM were the significant factors which affected the selling decision of groundwater.

5.3 Productivity, equity and employment levels

This section discusses the effects of the structure of groundwater markets on cropping pattern, input use and their share in total cost, returns, productivity, equity and employment.

5.3.1 Cropping pattern

Soil type, size of holding, availability of irrigation facilities and other resources, level of investment and marketing facilities etc. mainly influence the cropping pattern within an agro-climatic area. They provide information regarding the intensity with which the farmers are using their land and other resources. The cropping pattern followed by the farmers under different forms of water market was analysed and results are presented in Table 5.3.1.

Sugarcane (ratoon and planted) occupied the highest proportion of total cropped area, followed by wheat and *kharif* fodder (mainly Jowar). Sugarcane being a cash crop and wheat being a staple food crop, dominated the cropping pattern in the study area. The other crops though grown in a smaller proportion were rice, barley, *rabi* fodder (berseem, oat etc.), pulses (black gram and green gram), rapeseed & mustard etc..

A comparison of cropping patterns among different forms of water market showed that sugarcane based specialised farming (i.e. occupying more than 50 per cent of the total cropped area) was found under almost all forms of water market. However, under purely buyers, the share of sugarcane was marginally less which accounted for nearly 47 per cent of the total cropped area. The assured irrigation facility under other forms of water market in comparison to purely buyers was appeared to be a major factor responsible for higher

Table 5.3.1 **Net sown and total cropped area, cropping and irrigation intensity, and cropping pattern across the water markets**

Particulars	Purely buyers	Owners+ buyers	Owners+ buyers+ sellers	Owners+ sellers	Purely owners
Net area sown (ha)	59.68	55.52	109.38	82.34	80.56
Total cropped area (ha)	91.64	83.22	158.10	123.60	121.58
Cropping intensity (%)	154	150	145	150	151
Irrigation intensity (%)***	144	146	140	149	150
Share of different crops in gross cropped area (%)					
Wheat	29.36	27.64	25.33	25.63	24.91
Sugarcane (Ratoon)	25.67	29.70	30.28	30.45	30.24
Sugarcane (Planted)	20.95	23.74	24.67	24.17	23.06
Rice	0.35	1.01	1.32	1.10	1.67
Barley	0.35	0.48	0.81	1.10	1.45
Fodders:					
Kharif	17.11	11.63	10.75	9.03	10.23
Rabi	4.86	4.40	5.30	5.73	5.41
Others	1.35	1.39	2.54	2.79	3.03

***Indicates the difference between the water markets are significant at 10% level.

acreage allocation to sugarcane. Wheat and *kharif* fodder crops especially jowar occupied higher proportion of cropped area under purely buyers. Inadequate irrigation facilities was an influencing consideration for purely buyers to allocate more area under jowar thereby availability of land for *rabi* cultivation particularly, wheat crop. It was interesting to note that WEM owners preferred to grow high water requiring crops on the fragments where they are able to use their own WEMs and low water requiring crops on that fragments where they were water buyers.

The cropping intensity was found to be highest (154 per cent) for purely buyers forms of water market followed by purely owners. Adoption of short duration crops befitting double cropping system by the purely buyers was the probable reason for high cropping intensity. The variation in the cropping intensity among the various forms of water market was also due to extent of area devoted to sugarcane crop by the farmer under respective forms of water market. Since sugarcane was a single crop in working out the cropping intensity, farmers devoted a larger proportion of area under sugarcane thereby realising lower cropping intensity. However, the analysis of variance indicated that these differences were non-significant among various forms of water market.

Irrigation intensity defined as gross irrigated area to net irrigated area was found to be higher under owner category (purely owners and owners+sellers) than that in buyer category (purely buyers, owners+buyers and owners+buyers+sellers) of water markets as it was expected. It was found to be highest for the owners purely (151 per cent), followed by owners+sellers (150 per cent). The irrigation intensity was lower under owners+buyers+sellers type of water markets because of lower cropping intensity and preference of farmers to irrigate high value crops. The analysis of variance showed that irrigation intensity differed significantly under various forms of water market.

The foregoing discussion revealed that there was a preference in favour of remunerative crops like sugarcane in the cropping pattern in all forms of water market. Even in the case of purely buyers who had relatively lower share for sugarcane, nearly 47 per cent of total cropped area falls under this crop. Irrigation intensity was higher for the owner category as compared to buyer category of water markets.

5.3.2 Input use and their share in total input cost

Costs structure of major crops play an important role in decision making of the farmers for choosing the most profitable crop enterprise mix in the cropping system. Sugarcane and wheat crops occupied more than three fourth of cropped area on the sample farms. The effect of different forms of water market on changes in the level of input use, their costs and share in total input cost of cultivation associated with sugarcane, wheat and all crops together will be of importance in understanding the dynamics of this decision making process. Hence, an attempt has been made to analyse this aspect separately.

5.3.2.1 All crops together

The level of input use and their share in the total input cost per hectare for all crops together grown on the farms under different forms of water market are presented in Table 5.3.2.1. It is evident that the total input cost varied considerably among the different forms of water market. The farmers under purely buyers category incurred comparatively lower expenses on inputs due to their poor resource endowment and uncertain accessibility to groundwater. The expenditure is found to increase with better accessibility to groundwater.

Among the various inputs, the cost of human labour constituted the major share in total cost irrespective of forms of water market (45 to 46 per cent). This was followed by the chemical fertilisers and irrigation, constituting nearly

Table 5.3.2.1 **Level of inputs use and their share in the total input cost per hectare for all crops under different forms of water market**

Particulars	Purely buyers	Owners+ buyers	Owners+ buyers+ sellers	Owners+ sellers	Purely owners
Human labour					
Level of use (days)	205	229	217	231	227
Wage rate (Rs/man day)	36.84	36.95	36.94	37.52	37.92
Share in total cost (%)	44.34	45.74	46.44	45.88	45.67
Animal power					
Level of use (days)	13.47	10.97	11.26	9.16	10.57
Price (Rs/pair day)	86.86	92.64	85.44	85.93	86.11
Share in total cost (%)	6.87	5.35	5.57	4.17	4.83
Farm machinery					
Level of use (hours)	12.38	14.82	13.67	16.33	13.64
Price (Rs/hour)	116.75	110.17	104.18	112.11	122.60
Share in total cost (%)	8.48	8.82	8.25	9.69	8.87
Irrigation					
Level of use (hours)	201	253	245	271	272
Price (Rs/hour)	8.80	9.13	8.71	9.09	8.87
Share in total cost (%)	10.39	12.50	12.34	13.02	12.78
Seed					
Share in total cost (%)	10.24	9.67	10.09	9.34	9.47
FYM					
Share in total cost (%)	5.18	3.56	3.76	3.61	3.71
Fertilisers (nutrients)					
Level of use (Kgs)					
N	232	270	232	274	279
P	43	37	37	39	39
NPK	275	308	268	313	318
NPK price (Rs/Kg)	8.13	7.75	7.95	7.83	7.86
Share in total cost (%)	13.13	12.90	12.36	12.96	13.25
Plant protection					
Share in total cost (%)	1.36	1.32	1.19	1.32	1.41
Total input cost (Rs)	17032	18497	17264	18889	18847

accessibility to groundwater and adoption of high value crops could be the likely reason for higher level of use of chemical fertilisers in the study area. However, the use of plant protection measures , FYM and animal power were found to be lower as reflected by their share in total cost. There is a clear indication of the fact that crop production in the study area is still labour intensive although there is a tendency to replace animal power with farm machinery.

The quantum of human labour use was highest on owners+buyers farms followed by owners+sellers farms and least on purely buyers farms. The reliable irrigation resource endowment of the owners provided an incentive for proportionately higher cultivation of high value and labour intensive crops like sugarcane which resulted in higher use of farm labour. However, there was no substantial variation in the use of animal power, farm machinery and seed. The same was true in the case of plant protection chemicals also. There was a marked variation in the use of irrigation and chemical fertiliser across the various forms of water market. Purely owners and owners+sellers were found to be using more of irrigation as compared to other forms of water market by virtue of their sufficient availability of groundwater resource.

5.3.2.2 Sugarcane

In order to study the effect of water markets on the costs, returns and employment potential, sugarcane planted as well as ratoon crops were considered together, since most of the inputs used and agronomic practices followed in planted crop have their significant bearing on ratoon crop. However, their use effect can not be decomposed for planted and ratoon crop separately. Secondly, the ultimate objective of the study entails in examining the influence of water markets not the comparision over planted and ratoon crop of sugarcane.

An examination of per hectare cost structure revealed that on an average, human labour constituted highest share in total inputs cost, followed by irrigation, chemical fertilisers, seed, animal labour, farm machinery and FYM (Table 5.3.2.2). Unlike other crops, the share of planting materials (i.e., an average for planted and ratoon crops) in total input cost of cultivation was considerably high, indicating the importance of seed input in sugarcane. The cost on plant protection measures accounted merely around 2 per cent of the total cost under all forms of water market.

The comparison of the cost components across the different forms of water market showed that the use of human labour did not vary substantially across the various forms of water market except for the purely buyers, where it was least on account of less number of irrigation given by this group of farmers than others. The poor accessibility of groundwater to purely buyers could be the probable reason for this, thereby resulting in lower yields and lower demand of human labour. The use of on farm inputs such as animal power, seed and FYM was highest under purely buyers. On the contrary, purchased inputs like the level of use of tractor power, irrigation and fertiliser was highest either on owners+sellers or purely owners farms. It illustrated the use of various inputs among the various forms of water market. While, purely owners and owners+sellers had a more intensive use of capital embodied inputs like farm machinery and irrigation, the purely buyers placed more thrust on traditional inputs like animal power and seed. Ultimately the total input cost of cultivation was the highest under owners+sellers and the least under purely buyers. This clearly indicated that the level of use of purchased inputs was correlated positively with farmers' accessibility/controllability to groundwater.

Table 5.3.2.2 **Level of inputs use and their share in total input cost per hectare for sugarcane crop under different forms of water market**

Particulars	Purely buyers	Owners+ buyers	Owners+ buyers+ sellers	Owners+ sellers	Purely owners
Human labour					
Level of use (days)	177	187	188	188	187
Wage rate (Rs/man day)	35.57	35.89	35.27	36.62	36.17
Share in total cost (%)	46.21	47.41	48.02	47.76	47.03
Animal power					
Level of use (days)	8.85	7.26	7.34	5.45	7.19
Price (Rs/pair day)	85.42	99.41	85.01	84.45	86.60
Share in total cost (%)	5.55	5.10	4.53	3.18	4.33
Tractor power					
Level of use (hours)	3.03	4.11	4.40	7.09	4.21
Price (Rs/hour)	160.35	141.59	125.39	101.27	150.13
Share in total cost (%)	3.57	4.11	4.00	4.97	4.40
Irrigation					
Level of use					
Number	7.65	8.72	8.88	9.36	9.16
Hours	173	202	211	225	223
Hours/irrigation	22.60	23.22	23.73	24.04	24.30
Price (Rs/hour)	9.09	9.36	9.16	9.45	8.93
Share in total cost (%)	11.54	13.40	14.01	14.71	13.81
Seed					
Level of use (qtls)	26	26	25	26	25
Price (Rs/qtl)	66.78	64.70	66.02	65.87	65.55
Share in total cost (%)	12.85	11.84	12.12	11.70	11.20
FYM					
Share in total cost (%)	5.43	3.95	3.83	3.56	3.92
Fertilisers (nutrients)					
Level of use (Kgs)					
N	210	230	208	235	247
P	22	15	17	15	18
NPK	234	245	226	250	265
NPK price (Rs/Kg)	7.31	6.97	7.16	7.01	7.18
Share in total cost (%)	12.57	12.07	11.71	12.15	13.22
Plant protection					
Share in total cost (%)	2.29	2.11	1.78	1.98	2.09
Total input cost (Rs)	13624	14149	13784	14448	14381

5.3.2.3 Wheat

Wheat is the staple food in the study area. It was grown in *rabi* season under irrigated conditions on all types of farms. As in sugarcane, human labour constituted the highest share in the cost of cultivation (Table 5.3.2.3). This was followed by chemical fertiliser, which accounted for nearly 18 per cent of the total cost. The share of plant protection chemicals and micro nutrients (zinc sulphate) was the least. Though human labour constituted around 32 per cent of the cultivation expenses, indicating thereby a labour intensive nature of wheat production. The extent of farm mechanization was restricted only to tractor and power thresher. The threshing was carried out exclusively by power threshers.

Comparison of the pattern of input use among the various forms of water markets depicted the same trend as was observed in the case of sugarcane cultivation. Purely buyers using more traditional farm inputs like FYM and animal power, while owners+sellers and purely owners on account of better accessibility and economic conditions, used more of capital embodied inputs like tractor power and irrigation, which ultimately increased their cost of cultivation as compared to the other forms of water market. The above analysis clearly established the facts that better accessibility and controllability to groundwater at farm level acted as an incentive for more intensive use of purchased inputs and human labour.

5.3.3 Farm business analysis

The success and/or failure of the farm business from the farmers' point of view depends upon the returns which he is earning from his own resources. In this section, different cost concepts and corresponding income for

Table 5.3.2.3 Level of inputs use and their share in total input cost per hectare for wheat crop under different forms of water market

Particulars	Purely buyers	Owners+ buyers	Owners+ buyers+ sellers	Owners+ sellers	Purely owners
Human labour					
Level of use (days)	73	74	74	77	74
Wage rate (Rs/man day)	46.25	48.65	48.55	47.28	47.73
Share in total cost (%)	31.95	32.91	32.69	31.11	31.50
Animal power					
Level of use (days)	10.7	9.0	9.4	9.5	8.5
Price (Rs/pair day)	88.89	85.45	86.97	85.35	85.88
Share in total cost (%)	8.98	7.02	7.49	6.95	6.54
Tractor power					
Level of use (hours)	6.5	8.0	10.8	11.4	9.4
Price (Rs/hour)	148.32	147.27	106.25	112.88	130.14
Share in total cost (%)	9.13	10.79	10.54	11.07	11.00
Irrigation					
Level of use					
Number	5.20	5.47	5.68	5.74	5.80
Hours	113	133	128	132	138
Hours/irrigation	21.83	24.36	22.60	23.00	23.72
Price (Rs/hour)	8.83	8.30	8.96	9.47	8.52
Share in total cost (%)	9.24	10.08	10.54	10.73	10.54
Seed					
Level of use (kgs)	147	145	148	150	150
Price (Rs/kg)	4.65	4.75	4.91	4.86	4.98
Share in total cost (%)	6.44	6.27	6.63	6.24	6.74
FYM					
Share in total cost (%)	5.54	3.64	3.60	5.42	4.86
Fertilisers (nutrients)					
Level of use (Kgs)					
N	143	148	140	150	148
P	52	55	56	57	54
NPK	197	205	196	207	202
NPK price (Rs/Kg)	9.60	9.64	9.80	9.69	9.63
Share in total cost (%)	17.98	18.00	17.57	17.15	17.50
Plant protection and Micro nutrients					
Share in total cost (%)	0.06	0.17	0.13	0.33	0.33
Thresher					
Level of use (hours)	13.6	12.6	14.0	13.3	12.5
Price (Rs/hour)	83.51	96.75	84.44	96.38	98.15
Share in total cost (%)	10.69	11.11	10.81	10.98	10.99
Total input cost (Rs)	10602	10976	10920	11664	11124

all crops together, sugarcane and wheat crops were examined under different forms of water market. The costs concepts used in analysing the farm business are given in Appendix III. In order to make the comparison more sensible, the analysis is done on per hectare basis rather than per farm which size of operational holdings varied widely.

5.3.3.1 All crops together

Costs and returns used in farm business analysis were higher under owner category and lower on buyer category of water markets. The differences between higher and lower costs among the various forms of water market increased in absolute terms due to the high variation in the variable input use except human labour, rental value of land and other fixed costs (Table 5.3.3.1).

As discussed earlier, the WEM owners devoted higher proportion of their land under high value crops like sugarcane due to better accessibility and reliability of groundwater, which in turn resulted in higher gross return per hectare of cultivated area. The gross income, net income and farm business income were found to be lowest for purely buyers followed by owners+buyers or owners+buyers+sellers. This could be attributed to the relatively higher use of family labour by purely buyers and owners+buyers, and poor resource management on their fragmented land by owners+buyers+sellers. The negative net income over cost C_3 on the purely buyers' farms could be due to poor resource endowment and managerial skill.

5.3.3.2 Sugarcane

The examination of farm business analysis of sugarcane, the most important cash crop showed that purely owners incurred higher paid out costs (cost A_1), followed by owners+sellers . The farmers under purely buyers and

Table 5.3.3.1 Farm business analysis of all-crops together under different forms of water market

(Rs /ha)

Particulars	Purely buyers	Owners+ buyers	Owners+ buyers+ sellers	Owners+ sellers	Purely owners
Cost A1	11917	14631	14780	15772	16173
Cost A2	12036	14946	14832	16278	16173
Cost B1	16253	19766	19146	21308	21728
Cost B2	28103	32606	32116	34408	34828
Cost C1	22808	25711	23311	26668	26623
Cost C2	34658	38551	36281	39768	39723
Cost C3	38124	42406	39909	43745	43695
Gross income	37253	42598	40643	44516	43865
Farm business income	25336	27967	25863	28744	27692
Family Labour income	9150	9992	8527	10108	9037
Net income over cost C1	14445	16887	17332	17848	17242
Net income over cost C2	2595	4047	4362	4748	4142
Net income over cost C3	-871	192	734	771	170

owners +buyers incurred less paid out costs. In terms of cost C_1, cost C_2 and cost C_3, higher costs were incurred by owners+sellers, followed by purely owners (Table 5.3.3.2). On the other hand, these costs were found to be least under purely buyers, followed by owners+buyers+ sellers.

Table 5.3.3.2 Farm business analysis of sugarcane crop under different forms of water market

(Rs/ha)

Particulars	Purely buyers	Owners+ buyers	Owners+ buyers+ sellers	Owners+ sellers	Purely owners
Yield (Qtls/ha)	487	552	546	586	576
Cost A1	10495	12382	13095	13407	13681
Cost A2	10565	12587	13129	13741	13681
Cost B1	13053	15720	15977	17061	17312
Cost B2	21941	25350	25705	26886	27137
Cost C1	17713	19559	18377	20304	20175
Cost C2	26601	29189	28105	30129	30000
Cost C3	29261	32108	30916	33142	33000
Gross income	31973	36390	35694	38469	37630
Farm business income	21478	24008	22599	25062	23949
Family Labour income	10032	11040	9989	11583	10493
Net income over cost C1	14260	16831	17317	18165	17455
Net income over cost C2	5372	7201	7589	8340	7630
Net income over cost C3	2712	4282	4779	5327	4630

Like all crops, in case of sugarcane too, the yields as well as the returns under owners+sellers were found to be highest. This may be attributed to better access to groundwater and consequently higher and better utilization of other purchased and farm inputs. Lower gross return, farm business income and family labour income were realised by the farmers under purely buyers followed by owners+buyers+sellers due to lower yield realization. The net income was again lowest for purely buyers followed by owners+buyers due to comparatively higher use of family labour. The net income over cost C_3 was positive under all forms of water market, indicating thereby the remunerativeness of sugarcane cultivation. The results presented in the table clearly indicated the responsiveness of sugarcane crop to better accessibility and controllability of groundwater.

5.3.3.3 Wheat

The farm business analysis of wheat showed an entirely different trend than that of sugarcane. The owner category incurred higher paid out costs. It was comparatively low for the purely buyers and owners+buyers forms of water markets (Table 5.3.3.3). The yields and gross returns were highest on the farms of owners+sellers, followed by the purely owners. However, the differences in gross returns and yields in between buyer category and owner category were modest. Higher farm business income and family labour income was realised by buyer category for wheat because of lower paid out cost, rental value of land and fixed investment per unit of land. Interestingly, the buyers were reported to have a better access to groundwater in the winter season and lower access during the summer season. This makes buyers to reduce their area from high water requiring crop one like sugarcane to low water requiring crops, thereby realising relatively low return per unit of their cultivated land. Surprisingly, the net income over cost C_2 and C_3 were negative for all types of water markets. This clearly indicated that the returns were not commensurate with high rental value of land and managemental charges.

From the foregoing discussion, it is summarised that, wheat being the major staple food and cattle feed crop, farmers are compelled to raise this

Table 5.3.3.3 Farm business analysis of wheat crop under different forms of water market

(Rs/ha)

Particulars	Purely buyers	Owners+ buyers	Owners+ buyers+ sellers	Owners+ sellers	Purely owners
Yield (Qtls/ha)	38.31	39.56	41.02	41.68	41.54
Cost A1	8776	9756	10178	10751	10486
Cost A2	8803	9822	10188	10847	10486
Cost B1	9773	10834	11008	11803	11541
Cost B2	15698	17254	17493	18353	18091
Cost C1	12248	12859	12310	13492	12935
Cost C2	18173	19279	18795	20042	19485
Cost C3	19990	21207	20675	22046	21434
Gross income	17414	17802	18331	18563	18432
Farm business income	8638	8046	8153	7812	7946
Family Labour income	1716	548	838	210	341
Net income over cost C1	5166	4943	6021	5071	5497
Net income over cost C2	-759	-1477	-464	-1479	-1053
Net income over cost C3	-2576	-3405	-2344	-3483	-3002

though, the sugarcane seems to be highly remunerative. The differences in costs and returns were more pronounced in sugarcane as compared to wheat. The accessibility to groundwater during the summer season being very critical for sugarcane cultivation, appeared to be the main reason for the variation in cost and returns from sugarcane across forms of water market.

5.3.4 Equity analysis

Equity consideration is of great relevance in order to develop sustainable groundwater irrigation. As discussed earlier, the level of input use and yield realised varied widely under different forms of water market. However, the earlier analysis did not assessed the two dimensions of equity viz., the horizontal equity with regard to access to groundwater and vertical equity in terms of yield differences among different farm sizes. Therefore, these issues were examined under the different forms of water market and discussed under separate heads.

5.3.4.1 Horizontal equity

Horizontal equity is defined as the conditions of equal access to groundwater, facilitating an equal level of human labour and fertiliser use thereby, an even yield realisation among the various forms of water market. Number of irrigation was taken as a proxy for actual volumetric measurement of groundwater. An important input, chemical fertilisers (plant nutrients) application per hectare were taken into consideration to assess the equity. Another important indicator used was the average yield under different forms of water market. As mentioned in the methodology, analysis of variance and Scheffe Test were used to examine these issues in two major crops, viz., sugarcane and wheat.

The results of analysis of variance indicated that number of irrigation and application of nitrogenous and total plant nutrients varied widely, thereby wide variation were observed in sugarcane yield among various forms of water market (Table 5.3.4.1). The differences in the use of phosphatic fertiliser

Table 5.3.4.1 **Level of irrigation and fertilisers use, and yield achieved in sugarcane crop under different forms of water market**

Water markets	Irrigation* (Numbers)	Fertilisers (kg/ha) N*	P_2O_5	NPK**	Yield* (Qtls/ha)
Purely buyers	7.65	210	22	234	487
Owners+buyers	8.72	230	15	245	552
Owners+buyers+sellers	8.88[a]	208	17	226	546
Owners+sellers	9.36[a]	235	15	250	586[a]
Purely owners	9.16[a]	247[b]	18	265	576[b]

* and ** indicate that different forms of water market differ significantly at 1 % and 5 % level, respectively.

'a' and 'b' indicate that the difference from purely buyers is significant at 1 % and 10 % level, respectively.

was non-significant. The scheffe test indicated that number of irrigation applied by purely buyers (7.65) were significantly different from the irrigation applied by owners+ sellers (9.36), purely owners (9.16) and owners+buyers +sellers (8.88). Application of nitrogenous fertilisers and total plant nutrients differed significantly between purely buyers and purely owners. As a result, purely buyers realised substantially lower yield (487 qtls) than that of owners+sellers (586 qtls) and purely owners (576 qtls).

In case of wheat crop, the number of irrigation applied and yield achieved differed significantly among various forms of water market (Table 5.3.4.2). The Scheffe test indicated that the differences between purely buyers on the one hand and owners+sellers and purely owners on the other were significant. However, the differences in fertilisers use was found to be non-significant.

Table 5.3.4.2 Level of irrigation and fertilisers use, and yield achieved in wheat crop under different forms of water market

Water markets	Irrigation* (Numbers)	Fertilisers (kg/ha) N	P_2O_5	NPK	Yield** (Qtls/ha)
Purely buyers	5.20	143	52	197	38.31
Owners+buyers	5.47	148	55	205	39.56
Owners+buyers+sellers	5.68	140	56	196	41.02
Owners+sellers	5.74[a]	150	57	207	41.68[b]
Purely owners	5.80[a]	148	54	202	41.54[b]

* and ** indicate that different forms of water market differ significantly at 1 % and 5 % level, respectively.

'a' and 'b' indicate that the difference from purely buyers is significant at 1% and 10 % level respectively.

The foregoing analysis illustrated that purely buyers had poor access to groundwater irrigation which resulted in lower use of fertilisers thereby, effecting crop yield than owners+sellers and purely owners forms of water market. However, the inequalilty in realisation of gains was relatively less in wheat than in sugarcane cultivation.

5.3.4.2 Vertical equity

The vertical equity analysis examines the equity in access of farmers of different farm size to groundwater within a particular form of water market. The analysis was carried out by observing the effect of size of holding on the yield of sugarcane and wheat, where yield is taken as a proxy for access to groundwater together with other inputs.

The estimated regression parameter of land showed an inverse relationship between farm size and yield of sugarcane and wheat under almost all forms of water market. This relationship was statistically significant under owners+buyers+sellers for sugarcane, and owners+buyers and owners+sellers for wheat in terms of F-ratio. The R^2-values in these cases were found to be very low. In other words, the accessibility of groundwater under specific form of water

Table 5.3.4.3 Relationship between farm size and yield under different forms of water market

Water Markets	Constant	Elasticity	R^2	F-value
		Sugarcane		
Purely buyers	6.2525	-0.1355	0.04	1.7583
Owners+buyers	6.3765	-0.0035	0.001	0.0046
Owners+buyers+sellers	6.5288	-0.0934**	0.16	5.9843**
Owners+sellers	6.3867	-0.1627	0.01	0.2298
Purely owners	6.3995	-0.0077	0.003	0.0088
All farms	6.3558	0.0050	0.002	0.0299
		Wheat		
Purely buyers	3.8765	0.0169	0.002	0.1023
Owners+buyers	3.9475	-0.0696**	0.12	3.1459**
Owners+buyers+sellers	3.9595	-0.0190	0.01	0.3870
Owners+sellers	4.0002	-0.0719**	0.15	7.0069**
Purely owners	3.9081	0.0339	0.03	0.8242
All farms	3.9215	-0.0023	0.001	0.0204

** significant at 5 % level.

market do not varied across the farm size, thus variation in yield was on account of other than the variation in accessibility of groundwater. It is worth mentioning that the farm size effect in these regression equations were negative implying thereby the equity accessibility of groundwater. The estimated regression parameter of land for all farms also indicated that access to ground water varied between sugarcane and wheat crop. Since, sugarcane being an annual crop and summer season being its critical period, the inequity in access of groundwater for the crop could be attributed to the seasonal variation in access to groundwater.

5.3.5 Employment potential

As discussed earlier, the level of input use varied widely across various forms of water market. Employment potential generated in the cultivation as well as marketing of sugarcane, wheat and all other crops across the forms of water market were analysed and the results are presented in Table 5.3.5.

A perusal of table revealed that the use of human labour per hectare of net sown area was highest under owners+sellers and lowest under purely buyers. This difference may be due to the difference in cropping system followed by different categories of farmers due to difference in accessibility to groundwater. Employment potential was also low under owners+buyers+sellers, which could be attributed mainly to lower cropping intensity on the farms under this form of water markets. Almost same was the case in sugarcane crop as well. On the contrary, the variation in the use of human labour was minimal for wheat crop, implying thereby that the wheat production technology appeared to be more standardised particularly in the use of human labour and also the farmers under study area were relatively less constraints to the accessibility of groundwater in winter season crop than that in summer season crop.

Table 5.3.5 Employment levels in sugarcane, wheat and all-crops under different forms of water market

(man day/ha)

Water markets	Sugarcane			wheat			All crops		
	family	hired	total	family	hired	total	family	hired	total
Purely buyers	150	49	199	59	21	80	191	28	219
Owners+buyers	125	84	209	49	33	82	172	70	242
O+B+S*	83	125	208	32	50	82	121	108	229
Owners+sellers	111	103	214	43	43	86	146	90	244
Purely owners	101	111	212	36	47	83	141	101	242

* represents owners+buyers+sellers.

Decomposing the use of total human labour into family and hired labour showed substantial variation across the different forms of water market. The share of family labour was found to be highest on the farms under purely buyers followed by owners+buyers. This was mainly due to small size of holdings and easy availability of family labour for cultivation. The use of family labour decreased and hired labour increased as size of holdings increased under different forms of the water market.

From the above discussion it may be concluded that per hectare use of human labour had a tendency to increase with the increase in availability and controllability of groundwater under different forms of water market. The variation in the human labour was less in winter season crop like wheat than that of summer season crop of sugarcane.

5.4 Efficiency and reliability of water markets

Efficiency and reliability criterion are equally important to equity aspect of water markets which is discussed earlier. In this section, efficiency of water markets was examined with the help of resource productivity analysis, decomposition of productivity and cost of water extraction and selling price for WEMs, and reliability was examined with the help of farmers' perception.

5.4.1 Resource productivity

The tabular analysis presented earlier assessed the contribution of each input in the total cost of cultivation. A multi-variate analysis of the production process has been undertaken for each forms of water market separately, estimating the magnitude of contribution of inputs to output.

The linear, quadratic and Cobb-Douglas production functions were fitted to the data. The Cobb-Douglas production function (log-linear) which gave the best result was ultimately selected. Due to the presence of multicollinearity among the independent variables, the inputs were transformed on per hectare basis and size effect was thus removed. In the final run of transformed (per hectare) production function, human labour (in man days), number of irrigation and fertilisers (plant nutrients in kg) were included as explanatory variables.

The estimated parameter of Cobb-Douglas production function are the production elasticities of the factors employed. The elasticity of production of an input indicated that percentage change in the productivity associated with one per cent change in the quantity of that input keeping the other inputs at a specified level.

The elasticities of production of sugarcane along with standard errors and coefficient of multiple determination under different forms of water market are presented in Table 5.4.1.1. The independent variables considered could explain 34 per cent (under purely buyers) to 58 per cent (under purely owners) variation in production. Human labour had a positive and significant impact on the productivity under all forms of water market. The magnitude of regression coefficients of human labour indicated that production response of this input was more under purely owners, followed by owners+sellers, owners+buyers+sellers, purely buyers and owners+buyers forms of water market. This implied that more use of human labour by WEM owners would lead to greater productivity of sugarcane on their farms as compared to buyers.

Table 5.4.1.1 Production elasticities of factors influencing sugarcane productivity under different forms of water market

Variables	Purely buyers	Owners+ buyers	Owners+buyers +sellers	Owners+ sellers	Purely owners
Constant	2.3194	3.2334*	2.4322**	2.3953*	1.7645
	(1.5230)	(1.1088)	(0.9566)	(0.8107)	(1.4306)
Human labour	0.7081**	0.5920*	0.8207*	0.7436*	1.3996*
	(0.2923)	(0.1959)	(0.2025)	(0.1349)	(0.2844)
Irrigation	0.4946*	0.2639	-0.0576	-0.0770	-0.8565*
	(0.1709)	(0.2103)	(0.0803)	(0.1152)	(0.1958)
Fertilisers (NPK)	-0.1338	-0.09748	-0.0450	0.0593	-0.1428
	(0.1442)	(0.1370)	(0.0758)	(0.0800)	(0.1881)
R^2	0.34	0.38	0.32	0.55	0.58
No. of obrervations	45	26	41	35	31

* and ** indicate significant at 1 and 5 per cent level respectively.

The coefficient of irrigation, the most important input in modern agriculture, was found to be positive and significant for purely buyers suggesting thereby an increased use of irrigation would further increase the productivity of sugarcane on this type of farms. Irrigation coefficient however, was negative and significant for purely owners indicating thereby over utilisation of this resource. The regression parameter of irrigation was found non-significant for all other categories of water markets. In other words, any increase or decrease in the quantum of irrigation would not influence sugarcane production on the farms under these forms of water market. The production elasticity of fertilisers was found to be negative but non-significant in almost all the forms of water market.

In case of wheat, the non-significance of the factors included in the production function under various forms of water market indicate that wheat production technology has been standardised in the study area. Any deviation in the level of use of even the important variables, particularly irrigation and fertilisers are not going to affect the yield level under the existing production environment. This implies that the land being the major factor which influences the variation in wheat production, besides the other qualitative variables such as irrigation management etc. which were not included in the production equation. Due to this, the coefficient of multiple determination (R^2) has come down drastically (Table 5.4.1.2).

The regression coefficients of human labour and irrigation input were found to be positive but non-significant on the farms under all forms of water market. Positive and significant coefficient was found for irrigation under purely buyers, implying additional application of irrigation would lead to increase in yield of wheat on the farms under purely buyers. The coefficients of

Table 5.4.1.2 **Production elasticities of factors influencing wheat productivity under different forms of water market**

Variables	Purely buyers	Owners+ buyers	Owners+buyers +sellers	Owners+ sellers	Purely owners
Constant	1.4478**	2.0053**	2.3219*	1.0248*	2.6787*
	(0.7716)	(0.9117)	(0.7607)	(0.7891)	(0.7995)
Human labour	0.1892	0.3681	0.1065	0.0589	0.0289
	(0.1670)	(0.2322)	(0.1165)	(0.0975)	(0.1401)
Irrigation	0.4848*	0.0948	0.0581	0.1044	0.0774
	(0.1670)	(0.2481)	(0.1590)	(0.1546)	(0.2245)
Fertilisers (NPK)	0.1562**	0.0278	0.2020***	-0.0974	0.1893**
	(0.0803)	(0.1288)	(0.1174)	(0.1305)	(0.1026)
R^2	0.27	0.18	0.18	0.15	0.18
No. of obrervations	46	26	41	35	32

*, ** and *** indicate significant at 1, 5 and 10 per cent level, respectively.

fertiliser were positive and significant on the farms under purely buyers, owners+buyers+sellers and purely owners while, the same were non-significant on the farms under owners+buyers and owners+sellers farms. This indicated that an additional use of chemical fertilisers will increase the wheat productivity significantly in case of purely buyers, owners+buyers+sellers and purely owners.

The result of production function analysis clearly indicated the possibility of increasing the productivity of sugarcane and wheat by increasing number of irrigation on purely buyers' farms and reducing the same resource for sugarcane on purely owners farms. This in turn led to an increased availability of water to other crops particularly on buyers' farms. This may lead to a structural change in the production process on the farms having less accessibility to irrigation water. This clearly indicated that due to the existence of water markets, the lack of irrigation water to buyers has been minimised to the maximum possible extent.

5.4.2 Decomposition of productivity

Irrigation facilities under different forms of water market have influenced the use of inputs in crop production and timeliness of farm operation. It caused structural changes in production process and created a new production function. As a result of these factors, farmers were getting substantially higher yields under owners category (purely owners and owners+ sellers) of water markets compared to buyers category (purely buyers, owners+buyers and owners+buyers+sellers). This marked difference in yields among different forms of water market can be attributed partly to management especially irrigation water management and partly due to additional inputs used in crop production. Water management in terms of adequate, reliable and timely irrigation to crops as a qualitative input especially at critical growth stages of crops, improved the management of other resources and enhanced the crops productivity.

The increase in yield due to irrigation water management and input used were examined by comparing purely owners and owners+sellers versus purely buyers separately because equity analysis inferred that the purely buyers realised significantly lower yield than that of purely owners and owners+sellers. The decomposition model given in the methodology chapter, provides the mechanism for decomposing the total difference in yield among different forms of water market in their constituents i.e., better water management and changes in level of inputs. The results of the decomposition carried out for sugarcane and wheat crops are presented below.

5.4.2.1 Decomposition of sugarcane productivity

The productivity of sugarcane was observed to be sufficiently higher for purely owners and owners+sellers than purely buyers form of water markets. Water management accounted for about 15 to 23 per cent more yield on the farms under purely owners and owners+sellers compared to purely buyers form of water markets, respectively (Table 5.4.2.1). Contribution of water management implied that with the same level of inputs use, would produce more output per hectare on owners category of farms through better management of irrigation.

Table 5.4.2.1 Decomposition of total change in productivity of sugarcane among different forms water market

(Per cent)

Particulars	Purely owners versus Purely buyers	Owners+Sellers versus Purely buyers
Total change in productivity (actual)	15.93	18.01
Sources of change:		
(a) Change due to irrigation management	22.62	15.00
(b)Changes in inputs		
i) Human labour	7.69	4.48
ii) Irrigation	-15.43	-1.55
iii) Fertilisers	-1.78	0.39
Total change due to inputs	-9.51	3.32
Total change in Productivity (estimated)	13.11	18.33

Intensive use of human labour, number of irrigation and fertilisers per ha on the farms under purely owners resulted declining productivity by 9.51 per cent over purely buyers. Whereas, increase in yield was observed by 3.32 per cent for owners+sellers over the purely buyers. The decrease in productivity was due to higher use of chemical fertilisers and higher number of irrigation especially by the purely owners versus buyers category of water markets. Due to flat-tariff for electricity, WEM owners were found to be excessive users not economising the use of this resource. This aspect (flat-tariff for electricity) will have to be taken into consideration while formulating policy implications on groundwater markets.

5.4.2.2 Decomposition of wheat productivity

The results presented in Table 5.4.2.2 indicated that output per hectare of wheat was nearly 7 per cent higher on the farms under purely owners and owners+buyers over purely buyers form of water markets. The contribution of water management in terms of yield increase was estimated at around 4 to 6 per cent higher under purely owners and owners+sellers as against the purely buyers. However, the contribution of human labour to wheat yield was low and negligible under purely owners and owners+sellers over purely buyers type of water markets. As far as contribution of number of irrigation applied to wheat productivity is concerned, the owners category of farms achieved more than that of purely buyers. The fertilisers contribution to wheat productivity was observed on the farms under purely owners over purely buyers.

The above mentioned analysis clearly indicated that there was a close association between change in actual and estimated productivity of both the crops, viz., sugarcane and wheat. It also indicated that the decomposition

Table 5.4.2.2 Decomposition of total change in productivity of wheat among different forms water market

(Per cent)

Particulars	Purely owners versus Purely buyers	Owners+Sellers versus Purely buyers
Total change in productivity (actual)	6.85	7.10
Sources of change:		
(a) Change due to irrigation management	4.29	6.15
(b)Change in inputs		
(i) Human labour	0.11	0.47
(ii) Irrigation	0.93	1.15
(iii) Fertilisers	1.14	-0.78
Total change due to inputs	2.18	0.84
Total change in productivity (estimated)	6.47	6.99

equation used to measure the change in productivity yielded satisfactory results. It further revealed that management of irrigation water was an important determinant in increasing the crop yields. The role of management of irrigation water was more prominent in sugarcane crop than that of wheat. Sugarcane being an annual crop, its water requirement is much more than any other crop. The scarcity of water in summer due to irregular supply of electricity coupled with lower water extraction on account of depletion of water table on the one hand, requires management of irrigation water in sugarcane crop and over extraction than needed in other seasons due to flat charges of electricity on the other, requires managerial skill to adjust with the situation. These problems are not encountered in wheat crop which is grown in the *rabi* season. Higher use of fertilisers on the farms under owners category over purely buyers resulted in the negative contribution of fertilisers to sugarcane and wheat productivity. While excessive irrigation due to flat-tariff for electricity resulted in negative contribution of number of irrigation to sugarcane productivity. Therefore, improved water management alongwith the judicious use of its complementary input,viz; fertilisers has a greater role in enhancing the crop productivity in the area under study.

5.4.2.3 Additional gain accruing to irrigation management

Once it is established that irrigation water management have contributed a major share in increased yield of sugarcane and wheat crops, and that water management varied under different forms of water market. Next task will be to determine the additional gain and cost associated with the difference in water management under various forms of water market. Hence, the net gain and gain/cost ratio were computed for owners category (purely owners and owners+sellers) versus purely buyers form of water markets to judge additional gains attributable to better management of irrigation water.

A perusal of Table 5.4.2.3 shows that better management of irrigation water under purely owners and owners+sellers over purely buyers realised an additional gain of Rs. 2606 and Rs. 1754 per hectare in sugarcane, respectively. The additional cost per hectare was Rs. 553 and Rs. 415 per hectare on the farms under owners+sellers and purely owners over purely buyers,

Table 5.4.2.3 Additional gain and cost accruing to irrigation management

(Rs./ha)

Particularly	Purely owners versus Purely buyers	Owners+Sellers versus Purely buyers
	Sugarcane	
Total additional gain	2606	1754
Total additional cost	415	553
Net additional gain	2191	1201
Net gain/cost ratio	5.28	2.17
	Wheat	
Total additional gain	284	423
Total additional cost	194	273
Net additional gain	90	150
Net gain/cost ratio	0.46	0.55

respectively. Giving discount to this additional cost, the net gain realised was in the range of Rs. 1201 for owners+sellers to Rs. 2191 for purely owners over purely buyers. Further, the net gain/cost ratio was positive and greater than one ranging from approximately 5 for purely owners and 2 for owners+sellers over purely buyers.

In case of wheat, better management of irrigation water realised additional gain of Rs. 423 and Rs. 284 per hectare for owners+sellers and purely owners over purely buyers, respectively. The additional cost on was Rs. 273 for owners+sellers and Rs. 194 per hectare for purely owners over purely buyers leaving a net margin of Rs. 150 to Rs. 90 for owners+sellers to purely owners over purely buyers form of water markets. Net gain/cost ratio was positive but less than one in wheat.

From the above discussion, it is concluded that the farmers under owners category have realised substantial higher gain due to better water management of irrigation water in the production of sugarcane crop. However, this gains were low for wheat due to less variation in the availabilty of groundwater in winter season management of water resource in wheat production under all forms of water market.

5.4.3 Efficiency of water markets

The efficiency of water markets is further examined by analysing the cost of extraction and selling price of groundwater. If the cost of extraction is equal to the selling price, water markets can be considered as efficient. Selling price is greatly influenced by the cost of water extraction with other factor, viz., sources of energy, average installed horse power per WEM, size of outlet, water table, operating hours per irrigation per ha and average operating hours per year of a WEM etc.. Since, sources of energy are important factor which affect the cost of water extraction. The water markets efficiency for electric and diesel operated WEMs were examined and discussed separately.

5.4.3.1 Electric operated WEM

There were 86 electric operated WEMs owned by 127 farmers under individual and or joint ownership (Table 5.4.3.1). Average installed horse power per farm and per WEM was 5.71 and 8.40 respectively. The average size of outlet and depth of wells was found to be 4.06 inches and 43 feet, respectively.

Table 5.4.3.1 Total cost of water extraction and other details for electric operated water extraction mechanisms (1994-95)

Particulars	Units
A: General informations	
Number of owners' farms	127
Number of WEMs	86
Average horse power per farm	5.71
Average horse power per WEM	8.40
Average size of outlet (inch)	4.06
Average depth of wells (feet)	42.95
Average operating hours/ha/irrigation	23.50
Average operating hours per WEM per year	1438
Electricity charges per horse power year (Rs.)	600
B: Cost of water extraction (Rs. /hour)	
(I) Fixed cost on WEM:	5.89
	(46.86)
(i) Depreciation	1.47
	(11.70)
(ii) Interest	4.42
	(35.16)
(II) Operating cost on WEM:	6.68
	(53.14)
(i) Electricity charges	3.63
	(28.88)
(ii) Maintenance cost	2.67
	(21.24)
(iii) Interest	0.38
	(3.02)
(III) Total cost (I+II)	12.57
	(100.00)
(IV) Average selling price(Rs./hour)	6.89
Selling price/total cost ratio	0.55
Selling price/operating cost ratio	1.03

Figures in parentheses indicate percentage to the total cost.

Similarly, the average operating hours per irrigation per hectare was 24 hours and average operating hours per year of a WEM was 1438 hours.

The total cost of water extraction of an electric operated WEM worked out to be Rs. 12.57 per hour. Of the total, the share of fixed and operating cost accounted around 47 and 53 per cent, respectively. The interest on fixed capital constituted highest share (35 per cent) in total cost followed by the share of electricity charges (29 per cent). Though, the electricity tariff for agriculture in Uttar Pradesh was on the basis of flat rate of Rs. 50 per month per installed horse power of WEM, it was considered as a component of operating cost. The share of maintenance cost was around 21 per cent in the total cost. Depreciation constituted around 12 per cent share in the total cost of water extraction.

Average selling price of water extracted by electric operated WEMs was around Rs. 7 per hour. Surprisingly, selling price was markedly lower than that of the total cost of water extraction. The average extraction cost had a fixed component of Rs. 5.89 and an operating cost component of Rs. 6.68 per hour. Since, selling price was lower than total cost of water extraction, it implied that water markets were not efficient in pure market theory sense and water buyers were in better off position in comparison to WEM owners. However, there was no net gain due to water selling, the farmers on an average had a gross margin of Rs. 0.21 per hour, eventhough it may appear economically not attractive, the rationale of the farmers was that of recovering an amount over and above the electricity charges and the wear and tear through the sale of surplus water. Thus, the returns accrued from water selling was considered as a trade off for electricity tariff and cost of maintenance.

5.4.3.2 Diesel operated WEM

It is apparent from the Table 5.4.3.2 that there were around 33 diesel operated WEMs on the farms under study. They were operated by 27 tractors/engines and maintained by 30 farmers individual and or jointly. Average size of outlet was almost same but average depth of wells were less than half (18 feet) than that of electric operated WEMs. It indicates that diesel operated WEMS were installed in comparatively high water table areas. Diesel operated WEMs took lesser time (17 hours) to irrigate one hectare of land. It may be attributed to more water extraction per unit of time due to high water table and much efficient utilization of extracted water due to higher cost of water extraction. Average operating hours of diesel operated WEMs were also quite lower in comparison to electric operated WEMs. This phenomenon is explained by the fact that diesel operated WEMs were generally used to supplement the water requirement during the time of breakdown in electric supply in WEMs command area. However, a very small fraction of area was irrigated by purely diesel operated WEMs in the study area.

Though, the total cost of water extraction of a diesel operated WEM was very high (Rs 44.68/hour), the proportion of fixed and operating cost was almost same to electric operated WEMs. However, the share of fuel (diesel) accounted as high as 37 per cent, while cost on maintenance being 12 per cent. It explained the high cost on fuel and maintenance in operating this type of WEMs. Average selling price of groundwater extracted by diesel operated WEMs was around Rs. 30 per hour. The total cost of water extraction was quite high in comparison to selling price, thereby resulting selling price-cost ratio was less than one (0.66). On the other hand, selling price recovered all the operating expenses.

Table 5.4.3.2 Total cost of water extraction and other details for diesel operated water extraction mechanisms (1994-95)

Particulars	Units
A: General informations	
Number of owners' farms	30
Number of WEMs	33
Number of tractor/engine used	27
Average tractor/engine per WEM	1.23
Average size of outlet (inch)	4.00
Average depth of wells (feet)	18.00
Average operating hours per ha per irrigation	17.20
Average operating hours per WEM per year	166.15
Diesel consumption per WEM per hour (litre)	2.10
Diesel price per litre (Rs.)	7.50
B: Cost of water extraction (Rs./hour)	
(I) Fixed cost on WEM	21.15 (47.34)
(i) Depreciation	5.29 (11.84)
(ii) Interest	15.86 (35.50)
(II) Operating cost on WEM	23.53 (52.66)
(i) Fuel charges	16.75 (37.49)
(ii) Maintenance cost	5.45 (12.20)
(iii) Interest	1.33 (2.97)
(III) Total cost	44.68 (100.00)
(IV) Average selling price (Rs./hour)	29.53
Selling price/total cost ratio	0.66
Selling price/operating cost ratio	1.25

Figures in parentheses indicate percentage to the total cost.

Here too, the logic of the diesel operated WEM owners was to gain the liquidity to meet the expenses on diesel and a margin on the wear and tear of the machinery by selling water. This has resulted into selling groundwater at a price lower than the total cost of water extraction but above the operating expenses, thereby leaving a gross margin of Rs. 6.00 per hour.

The following conclusions emerged from the foregoing analysis. The groundwater markets were efficient in the study area because both sellers and buyers were mutually benefitted after the water transaction. The WEM owners were also spreading their over-head costs by selling groundwater and realising liquidity to meet the short run exigencies.

5.4.4. Reliability of groundwater irrigation

As discussed earlier, the owners category of water markets realised higher yields and consequently higher gains due to better water management. Reliability of irrigation influences the allocation of land and other resources to different crops and farm enterprises. Since diesel and electric operated WEMs were commonly used under all forms of water market, reliability of electric and diesel operated WEMs on different aspects of irrigation were examined by the farmers' perception and results are presented separately.

5.4.4.1 Electric operated WEM

A good proportion of farmers realised that they had an easy accessibility of electric operated WEMs to their farm locations under different forms of water market (Table 5.4.4.1). It was confirmed by the fact that 92 per cent of total irrigated land had access to electric operated WEMs (Table 5.2.2.1). Perception of easy accessibility to all the locations was higher under owners

Table 5.4.4.1 Farmers' perception about reliability of electric operated water extraction mechanisms under different forms of water market

(Per cent)

Factors	Purely buyers	Owners+ buyers	Owners+ buyers+ Sellers	Owners+ sellers	Purely owners
Respondents (number)	46	26	41	31	32
Easy accessibility to all locations	65	62	56	74	81
High frequency of breakdown	96	85	90	77	81
Adequate availability of water:					
-Kharif(monsoon)	83	89	91	96	93
-Rabi(winter)	57	65	70	76	73
-Zaid(summer)	4	4	3	6	6
Controlability of water supply:					
-Kharif(monsoon)	74	81	78	93	88
-Rabi(winter)	47	62	67	78	70
-Zaid(summer)	0	0	0	3	0
Availability during peak period:					
-Pre sowing	20	25	30	50	36
-Critical stage I	25	33	36	60	54
-Critical stage II	51	65	69	79	72
High water price	52	50	46	33	35
Customary charges for buying water	9	4	2	0	0

category in comparison to buyers category of water markets. This phenomenon was also explained by the extent of farm fragmentation which was least under owners category.

A good number of farmers under all forms of water market realised that the frequency of breakdown in electric supply was high. A good proportion of farmers under all forms of water market had adequate availability of and control on groundwater supply in monsoon season followed by winter season. The lower proportion of purely buyers realised adequate availability of and control on groundwater in comparison to other forms of water market. On the other hand, few farmers witnessed adequate availability of and control on groundwater in summer season. Farmers' perception about availability of groundwater for pre-sowing irrigation under all forms of water market was also poor. Even, less than half of the farmers of owners category realised availability of groundwater during pre-sowing period. This proportion improved significantly for succeeding stages of crop growth i.e. critical stage I and II.

Nearly fifty per cent of farmers under buyers category perceived that price of water extracted by electric operated WEMs was high, whereas only one third of the farmers of owners category were of the opinion that water price was high. Few farmers under buyers category perceived that they were asked to perform customary services in terms of weeding and cleaning of field channels, assistance in repair and maintenance of WEM and watching etc.

5.4.4.2 Diesel operated WEM

A perusal of Table 5.4.4.2 revealed that a good proportion of respondents under all forms of water market realised an easy accessibility of

Table 5.4.4.2 Farmers' perception about reliability of diesel operated water extraction mechanisms under different forms of water market

(per cent)

Factors	Purely buyers	Owners+ buyers	Owners+ buyers+ Sellers	Owners+ sellers	Purely owners
Respondents (number)	16	10	20	10	5
Easy accessibility to all locations	31	60	70	80	80
High frequency of breakdown	44	50	35	40	40
Adequate availability of water:					
-Kharif(monsoon)	100	100	100	100	100
-Rabi(winter)	100	100	100	100	100
-Zaid(summer)	59	70	85	100	100
Controlability of water supply:					
-Kharif(monsoon)	75	90	100	100	100
-Rabi(winter)	69	90	95	100	100
-Zaid(summer)	44	60	80	100	80
Availability during peak time:					
-Pre sowing	44	70	75	100	90
-Critical stage I	56	77	79	100	96
-Critical stage II	76	92	95	100	100
High water price	100	100	100	100	100
Customary charges for buying water	38	20	10	0	0

diesel operated WEMs to all the location of their holdings except purely buyers. This perception could be explained by the fact that 14-29 per cent of total irrigated area under different forms of water market had access (partially or fully) to diesel operated WEMs, even though electric operated WEMs were preferred due to low cost of water extraction (Table 5.2.2.3). Less than one-third respondents under purely buyers form of water market realised easy accessibility to diesel operated WEMs in all the locations. A good proportion of farmers under all the forms of water market perceived that frequency of breakdowns were low in diesel operated WEMs. Almost all the respondents of owners category realised that there had been adequate availability of water and control on water supply throughout the year even during critical period of crop growth. The same was observed by a good number of farmers under purely buyers except control on water supply during summer season and availability of water for pre-sowing irrigation.

The total respondents under all the forms of water market realised that price of groundwater irrigation by diesel operated WEMs was high. Some respondents of buyers category reported that they were asked to perform customary services as cleaning of irrigation channels, labour service for installation and repair etc.

From the foregoing discussion, it is inferred that a good number of farmers had easy accessibility to all the locations of their land to electric and diesel operated WEMs, simultaneously. Diesel operated WEMs were more reliable than electric operated WEMs, but the water price was high for diesel operated WEMs due to high cost of water extraction. Reliability of electric operated WEMs were less for purely buyers round the year, and even much lesser during summer season.

Chapter 6

Summary and Conclusions

Irrigation is one of the most important basic ingredients in the transformation of agriculture, especially in the Western Uttar Pradesh where rainfall is variable and inadequate. Initially, canal irrigation brought stability in agricultural production in the western region, but it could not cope fully with the irrigation needs of the intensive agriculture, which necessitated the need for higher exploitation of groundwater resource. Groundwater irrigation and modern crop production technology are strongly complementary to each other and together result in higher production. Therefore, policy makers and farmers have started giving more emphasis to the development of groundwater irrigation and modern water extraction mechanisms (WEMs).

However, the ownership of private modern WEMs were confined mostly to the larger farmers. The surplus water after meeting their own requirements were sold to the small and marginal, and resource poor farmers, who became the buyers to avoid the huge initial investments needed to install a WEM. Even large farmers, who had fragmented holdings and could not therefore install a WEM on each parcel of land, resorted to purchase of water from neighbouring WEM owners. This led to the emergence of water markets in the study area. Water markets generate many benefits to buyers such as higher and risk free income, and higher employment throughout the year. They also provide an opportunity to small and marginal WEM owners to increase WEM utilization and thereby to spread its over-head cost. However, the issues of efficiency and equity of groundwater markets were relegated to a secondary position under such a situation. It is in this context,the present study attempted to examine the efficiency and equity implications of groundwater markets on farm economy in Western Uttar Pradesh.

The specific objectives of the study were:

(1) to study the growth in groundwater development in Western districts of Uttar Pradesh,

(2) to examine the structure and determinants of groundwater markets,

(3) to examine the effect of groundwater markets on changes in cropping pattern,productivity, equity and employment, and

(4) to assess the reliability and efficiency of different forms of groundwater market and suggest suitable policy measures for sustainable use of groundwater.

The Western region of Uttar Pradesh was purposively selected which had proportionately higher area under groundwater irrigation. Among the districts, Meerut was chosen for detailed investigation because of its high water extraction mechanism (WEM) density. Out of the eighteen development blocks of Meerut district, two blocks were selected randomly. Finally, a cluster of two villages from each block were selected where farmers' dependence on groundwater for irrigation was high and a total of 180 farm households were selected randomly.

Primary as well as secondary data were used for examining the various objectives of the study. The time series data on irrigated area for the period 1951-52 to 1990-91 were compiled from the various issues of Indian Agricultural Statistics. Primary data on various aspects of water markets and crop production were collected through personal interview of the respondents with the help of specially structured, pre-tested schedule , pertaining to the agricultural year 1994-95.

The existing resource endowment, magnitude and dimension of the groundwater markets, and its effect on cropping pattern, costs and returns, productivity and employment were examined by tabular analysis. Compound growth rates were worked out by using exponential function to study the growth in groundwater and other irrigation infrastructure development in western districts of Uttar Pradesh for the period from 1951-52 to 1990-91 and also for the sub periods, viz., (i) the pre-green revolution period (1951-52 to 1966-67),(ii)the early green revolution period (1966-67) to 1977-78),(iii) the period of rapid growth (1977-78 to 1984-85, and (iv) the period of consolidation (1984-85 to 1990-91).

Logistic regression model was used to identify the various factors influencing the installation of WEM, groundwater purchasing and selling decisions of farmers. The analysis of variance (F-Test) and Scheffe test were carried out to examine the horizontal equity aspects of water markets. The productivity and farm size relationship was tested by the Cobb-Douglas production function in the context of vertical equity in accessing the groundwater. The resource productivity analysis was also carried out using Cobb-Douglas production function. Due to the presence of multi-collinearity, the variables were transformed on per hectare basis and a transformed production function was used. This helped to reduce the heterogeneity in land quality also. A decomposition analysis was carried out to capture the yield differences between two water markets on account of better irrigaton water management.

Growth in Groundwater Development

Irrigation development in general showed impressive growth during the past four decades. However, the growth differed during the sub-periods across the regions. Substantially higher growth visible during the early periods of green revolution which decelerated towards the later periods.

Among the various sources, groundwater dominated the irrigation development process, and its growth differed widely temporally and spatially. The quantum jump in groundwater development during the early stages of green revolution could not be sustained subsequently especially towards the consolidation period. The development of canal irrigation in the area was stagnant during the first three sub-periods and recorded a negative growth rate during the consolidation period. Greater development of tubewell irrigation resulted in farmers abandoning well irrigation which was a time and labour consuming process. This resulted in a large number of farmers converting the existing wells into tubewells. The lowering water tables on account of over exploitation of tubewell was another deterrent factor which reduced the reliability of well.irrigation. Thus, tubewell irrigation became the most popular source of irrigation.

The analysis amply illustrated the differences in the investment pattern in irrigation development in the region with a gradual shift in irrigation from public investment in canals to private investment in tubewells. The analysis also highlighted the reduction in inequity vis-a-vis irrigation whereby districts with low irrigation development showing relatively higher rate of growth than the others through private investments in tubewells.

The structure and determinants of groundwater markets

The area was predominated by smaller size holdings and moderate fragmentation. Nearly 82 per cent of the sample farms entered into one or the other form of water market activities. The area irrigated by buying groundwater accounted for 26 per cent of the net cultivated area, implying thereby that in the absence of groundwater markets, over one fourth land in the study area would have remained unirrigated. The area irrigated by buying groundwater varied from 16 per cent on large farms to 57 per cent on marginal farms, indicating the wide difference across the size groups.

Electric operated WEMs dominated the groundwater irrigation. Maintenance of diesel operated WEMs were relatively less and were confined to larger sized farms to ensure the availability of groundwater during the failure/breakdown of electric power supply. However, the farmers of buyers category had higher accessibility to both types of WEMs, viz., electric and diesel operated WEMs than that of owners category.

The determinants of farmers' decision to install an electric operated WEM were the size of (owned) operated holding number of farm fragments and the possibility of joint ownership during installation. Farmers with larger operational holding were more likely to own a WEM than a farmer with smaller operational holding. However, the higher fragmentation of the land was a deterrent to WEM ownership. As the joint ownership facilitated pooling of financial resources for installation and higher capacity utilization through collectivisation of the command area, it encouraged higher investment in WEMs. Off farm income, electricity tariffs, acreage ratio of sugarcane, educational attainment of the head of the family and family size did not exert any significant influence in the decisions to own an electric operated WEM. The logistic regression model developed for this purpose provided 83 per cent reliability in the prediction of farmers' decision. The perception analysis of farmers also reinforced the above factors encouraged the installation of WEMs. The important reasons for preferring diesel operated WEM were larger fragmentation, non-availability of canal water in its tail command area, multiple uses of diesel engine or tractor, low cost of installation, relatively higher control on irrigation water and ease in transportation.

The logistic regression model developed to predict the groundwater buying decision of the farmers had 79 per cent reliability. It identified the total operational area, number of fragments per farm, educational attainments (year of schooling) of the head of the family and the lack of provisions for the joint ownership of WEMs as the determinants of groundwater buying. The buying of groundwater was favoured by the farmers with small-sized holdings with low educational attainment and less probability of joint ownership of a WEM. The more the number of fragments, the more was the level of water buying. The tariffs on electricity, sugarcane acreage ratio, size of family and proportion of family workers and water prices were found to be non-significant factors influencing the water buying decisions of the farmers. The perception analysis of the farmers also gave identical results reinforcing the reliability estimated by the logistic regression model.

The significant factors determining the groundwater selling decisions of farmers in the area were the size of owned operational holding, number of farm fragments, possibility of joint ownership of WEMs and the horse power per unit of land. The large farmers had to install WEMs with higher horse power to irrigate more cultivated area. After meeting their own irrigation requirements, they were inclined to sell the surplus water to the small and marginal farmers who had neither the financial capacity nor the break-even land holding to spread the high overhead cost of installing a WEM of their own. This increased their capacity utilization also. Hence, the probability of selling water was also high when fragmentation increased. The tariff on electricity, sugarcane acreage ratio, year of schooling of the head of the family, selling price and proportion of non-farm income were found to be non-significant factors influencing the selling decision of farmers. The estimated logistic regression model had 71 per cent accuracy.

Effect of groundwater markets on productivity, equity and employment

The irrigation intensity and cropping pattern varied widely across the water markets. The owners category were found to grow high value crops on relatively larger area than that of buyer category on account of higher reliability of irrigation water. However, the analysis of variance showed that the differences in the cropping intensity of the different water market forms were not statistically significant.

The costs and return structure was in favour of owners category than that of the buyers of groundwater. No marked differences were observed in the use of human labour in the cultivation of all crops together or sugarcane and wheat individually across the various forms of water market except purely buyers. Purely buyers were found to use more traditional farm inputs like FYM and animal power, while owners category used more of capital inputs like irrigation, tractor power and chemical fertiliser resulting ultimately in higher total input cost for owners category and lower total input cost for purely buyers. The yield and gross return were also highest on the farms of owners category for wheat. The differences in costs and returns were more pronounced in sugarcane than in wheat.

The horizontal equity analysis of the water market employing the analysis of variance and the Scheffe test showed that inequity in the accessibility of groundwater existed, thereby differences in the use of fertilizer and realisation of crop productivity across the water markets. This inequity was relatively higher in sugarcane crop than in wheat. This resulted in purely buyers realising a substantially lower yield (487 qtls) than that of purely owners (576 qtls) and owners+sellers (586 qtls). In the case of wheat also the number of irrigation applied differed significantly among the different forms of water market. Scheffe test indicated that these difference were significant between purely buyers and owners category, resulting in lower yields for the purely buyers (38.31 qtls) as against the purely owners (41.54 qtls) and owner+sellers (41.68 qtls). The vertical equity analysis indicated that the different category of farmers were having equitable access to groundwater under a specific form of water markets.

The examination of the employment potential revealed that there existed a variation in employment generation across the water markets on account of variation in the accessibility to groundwater and resulting in sugarcane acreage variation. The reliability of groundwater irrigation was relatively more in winter season than that in summer season. Due to this, variation in the employment generation in wheat crop was minimal across the water markets

Efficiency and Reliability of different water market forms

The result of production function analysis revealed that irrigation influenced crop productivity significantly on the buyers farm. However, the excessive use of this factor resulted in negative contribution in sugarcane production and non-significant effect in case of wheat for the owners farm. This illustrated the possibility of increasing the productivity in sugarcane and wheat by reducing the excessive water use on the owners category of farms which in turn will increase the availability of water on buyers farm. This may lead to a structural change in production process on the farms having less accessibility to irrigation water.

The increase in productivity due to irrigation water management and resource use were estimated by comparing the per hectare production function of owners category versus purely buyers. The decomposition analysis revealed that irrigation management accounted for about 15 to 23 per cent more sugarcane productivity and nearly 7 per cent more wheat productivity under owners category over purely buyers form water markets. The scarcity of water in summer due to irregular supply of electricity coupled with low water extraction per hour due to lowering of water table calls for an efficient water management along with the judicious use of complementary inputs like fertilizer in enhancing the crop productivity.

None of the water extraction mechanisms were found to be financially efficient in the existing water market system. The average cost of water extraction for an electric and diesel operated WEM worked out to Rs. 12.57 and Rs. 44.68 per hour, respectively. While the selling price was Rs. 6.89 and Rs. 29.30 per hour with a selling price/cost ratio of 0.55 and 0.66 for electric and diesel operated WEM, respectively. However, both owners of the WEM and buyers of the groundwater were benefitted in one way or the other by the emergence of the groundwater markets. The WEM owners could spread their over-head costs by selling of groundwater. The rationale of farmers was that of recovering an amount over the fuel and maintenance cost through the sale of surplus water. The buyers were benefitted by the purchase at a cost less than total maintenance cost. They were saved from the financial commitment of heavy investments needed for the installation.

The reliability of groundwater in terms of adequacy in the summer season and availability for the pre-sowing irrigation was poor. Less than fifty per cent owners category of farmers experienced non-availability of groundwater during the pre-sowing season. In this respect, the diesel operated WEMs were more reliable but the higher cost of extraction made it an unattractive investment proposition.

Policy measures for sustainable groundwater use

The findings of the study give some clear indications regarding the strategy to be schemed that could to more efficient and equitable water markets based on a sustainable groundwater use:

Firstly, in view of the high WEM density than the norms prescribed, a system for licensing new WEMs giving greater emphasis for joint ownership benefitting marginal and small farmers is of immense importance. This would reduce the inequity in the accessibility to irrigation water and increase the sustainability of groundwater development.

Secondly, emergence of groundwater market benefits both owners as well as buyers across the farm size. However, the smaller sized farms are more benefitted. In order to achieve better distributive social justice and encourage efficient water market, suitable water price policy need to be evolved.

Thirdly, the neglect of canal water supply consequent to the development of groundwater facilities particularly in the tail command areas, resulting in the discontinuance of conjunctive use of surface and groundwater. This has resulted not only over-exploitation of groundwater but also reduced recharge of groundwater. This invites special attention of the policy makers to restore canal water supply to the extent possible which would increase the sustainability of groundwater in the long run.

Fourthly, the erratic electric supply compels farmers to install more than the optimum number of WEMs, thereby making them to bear high fixed cost per unit of water extraction. This calls for rationalisation of electric distribution system for a fixed and regular supply of electricity.

Finally, though sugarcane cultivation is remunerative and employment generating in nature, its persistent cultivation leads to over-exploitation of groundwater. Hence, a flexible cropping pattern incorporating remunerative but less water consuming crops need to be educated.

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Appendix-I Percentage of net sown area under irrigation in the districts of Western Uttar radesh in 1951-52

Districts	Percentage of area under irrigation	
	Total	Groundwater
Saharanpur	30	10
Muzaffarnagar	59	18
Meerut	65	28
Bulandshahr	61	33
Aligarh	58	31
Mathura	45	9
Agra	30	13
Etah	48	21
Mainpuri	57	26
Moradabad	20	18
Rampur	10	3
Bijnor	14	9
Bareilly	19	3
Budaun	20	18
Shahjahanpur	19	3
Pilibhit	17	1
Farrukhabad	33	18
Etawah	41	6
Western Uttar Pradesh	38	16
Uttar Pradesh	31	16

Source: Compiled from various issues of *Indian Agricultural Statistics* (DE&S, GOI).

Appendix-II Area irrigated by different sources in Western Uttar Pradesh

('000 Ha)

Years	Canal	Groundwater (Tubewell+ Other wells)	Net irrigated area	Gross irrigated area
1951-52	1180	955	2140	2538
1955-56	1053	935	2040	2329
1966-67	1226	1570	2855	3495
1977-78	1257	2694	4042	4904
1984-85	1258	3332	4727	6274
1990-91	1093	3521	4743	7178

Source: Compiled from various issues of *Indian Agricultural Statistics* (DE&S, GOI).

Appendix-III COST CONCEPTS

Cost A1 comprises the following :

1. Value of hired human labour;
2. Value of hired animal labour;
3. Value of owned animal labour;
4. Value of owned machinery labour;
5. Value of hired machinery;
6. Value of seed (farm grown and purchased);
7. Value of insecticides and pesticides;
8. Value of manure (owned and purchased);
9. Value of fertilisers;
10. Depreciation on implements and farm building;
11. Irrigation charges;
12. Land revenue and other taxes;
13. Interests on working capital;
14. Miscellaneous expenses.

Cost A2 = Cost A1 + rent paid for leased land.

Cost B1 = Cost A1 + interest on value of owned fixed capital (other than land).

Cost B2 = Cost B1 + rental value of owned land + rent paid for leased land.

Cost C1 = Cost B1 + imputed value of family labour.

Cost C2 = Cost B2 + imputed value of family labour.

Cost C3 = Cost C2 + 10 per cent of cost C2 to account for the value of management input of the farmer.

Source: *Agricultural Price Policy* by S.S. Acharaya and N.L. Agarwal.