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Groundwater Irrigation and Cropping Pattern in the Ganga-Brahmaputra Alluvial Plain of Burdwan District, West Bengal

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Abstract In this study, attempts have been made to overview the cropping patterns, the volume of groundwater used for different crops, total cost of cultivation per hectare including groundwater and net profits from different crops. The study has been conducted in the Katwa subdivision under the district of Burdwan, West Bengal, where both surface and groundwater are available for irrigation. Katwa subdivision is situated in the Ganga-Brahmaputra alluvial plain. Rice is the most dominant crop covered by 62%, and the remaining 38% by jute, potato, mustard, onion etc. Volume as well as cost of groundwater was maximum in the case of boro-rice and it was minimum in the case of jute. Cost of cultivation per hectare was maximum for onion and it was minimum for jute. The prices of agricultural commodities are usually determined by market factors of demand and supply. However, amount of profit per hectare was a maximum in the case of onion and was a minimum in the case of summer rice. Although, groundwater has played a key role in success of Green Revolution in India, excessive groundwater pumping can lead to the drying up of more shallow wells, requiring deeper tubewells, and increased pumping cost. From this study it may be suggested that to avoid the groundwater depletion and also to get higher returns, farmers should consider crop diversification. It should be recommended that although, rice is the main food in West Bengal a shift away from the rice-rice cropping pattern to rice-potato-onion-jute.

Keywords Cropping patterns, Groundwater, Groundwater pricing, Net income from crops, Crop diversification

1. Introduction

At present, India is the second largest rice producer in the world (155.682 million MT). West Bengal is predominantly an agricultural state and its economy depends on agriculture. In West Bengal, geoclimatic variations and agriculture's dependence on rainfall have resulted in three distinct rice growing seasons: kharif rice (June/July to November/ December); autumn rice (March/April to June/July); and boro or summer rice (November/December to May/June). The natural catastrophe like floods, droughts etc. hinder the agricultural development. Flood and drainage congestion generally destroy the kharif crop in north-eastern part of West Bengal. Therefore, farmers especially the small farmers have to obtain boro rice as a second crop, and for this they have to depend up on groundwater. Waterwells have helped small farmers to obtain a second (and even third) crop per year, and made irrigation possible beyond the canal command area of government irrigation projects. As a result of technological advances, groundwater use has spread rapidly in recent decades, increasing reliability of irrigation supplies, encouraging crop diversification and expanding the cropping season. Even in cases where lifting of groundwater is costly. the poor can benefit from buying water in informal groundwater markets (Palanisami 1994; Saleth 1998). Groundwater pumping has also brought immense benefits for safe drinking water supplies, particularly in rural areas. More than 1.5 billion people in the world rely on groundwater for their primary source of drinking water (Clark *et al*. 1996). Global, annual groundwater withdrawals have been estimated at 670–800 km^3. India, China, the United States, and Pakistan alone extract groundwater in the order of 325 km^3 every year (Shah *et al*. 2000; Shiklomanov 1998).

In India, the groundwater-irrigated area has increased 500% since 1960 (Shah, 2009). The green revolution was a major force in this growth. The adoption of new seeds and fertilizers provided great benefits and the benefits were the best under irrigation. Large investments had been undertaken in surface water projects to provide irrigation water to larger numbers of farmers. A number of other significant changes also took place in the late 60's and 70's (Brisco and Malik 2006). Electricity supply expanded in rural areas making

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pumping of groundwater easy and economical. Farmers realized that groundwater was abundant in many areas, especially in the large alluvial basins, and they could develop and apply water 'just in time' from groundwater sources, something which was not possible in the institutionally-complex and poorly managed canal systems. The result was a quite revolution, in which groundwater irrigation developed at a very rapid rate (Brisco and Malik 2006), while tank irrigation declined and surface water irrigation grew much more slowly.

However, the biggest problems resulting from groundwater use are overdrafting and deterioration of water quality. Previous studies showed that groundwater irrigated crops generally result in higher yields due to better water control, as compared to surface irrigated crops (Shah et al. 2000; Singh and Singh 2002). However, overdraft has taken on alarming proportions in several states, and has led to increased competition among irrigators, but also between irrigation and domestic water users.

Thus, there are both beneficial and harmful effects on groundwater use. The purpose of this study was to investigate the cropping sequences, economy of groundwater use, and cost of cultivation of different crops.

2. Methodology

This study was conducted in Katwa Subdivision under the Burdwan district. (12° 12' and 12° 33' north latitude and between 75° 55' and 76° 55' east longitude). Burdwan district has 31 blocks of which 5 blocks (Katwa I, Katwa II, Ketrugram I, Ketugram II and Mongalkote) under Katwa Subdivision (**Fig. 1**). Burdwan district with its varied tectonic elements and riverine features is a transitional zone between the Jharkhand plateau which constitutes a portion of peninsular shield in the west and Ganga-Brahmaputra alluvial plain in the north and east. Katwa subdivision is situated in the Ganga-Brahmaputra alluvial plain. In this region the alluvial soil is formed of allovium brought down by the Ajay, Bhagirathi and their tributaries. These soils are sandy, well drained and slightly acidic in nature.

Table 1. Average monthly rainfall: Burdwan district

Month	Stations (Blocks)			
	Katwa	Kalna	Mangolkote	Burdwan
January	14.4	12.7	6.6	11.2
February	24.1	20.4	20.3	24.6
March	28.2	34.5	28.2	25.0
April	45.2	63.0	38.6	46.1
May	122.9	129.8	117.6	114.8
June	247.9	234.7	255.8	196.0
July	284.5	285.2	259.3	314.4
August	278.6	266.5	270.8	310.2
September	187.7	196.1	173.2	2.36.5
October	112.0	90.4	74.4	106.8
November	20.1	20.3	17.3	23.0
December	2.5	3.6	2.5	4.3
Total	1365.1	1360.2	1264.6	1412.9

Source: Indian Metrological Department (1960-2000)

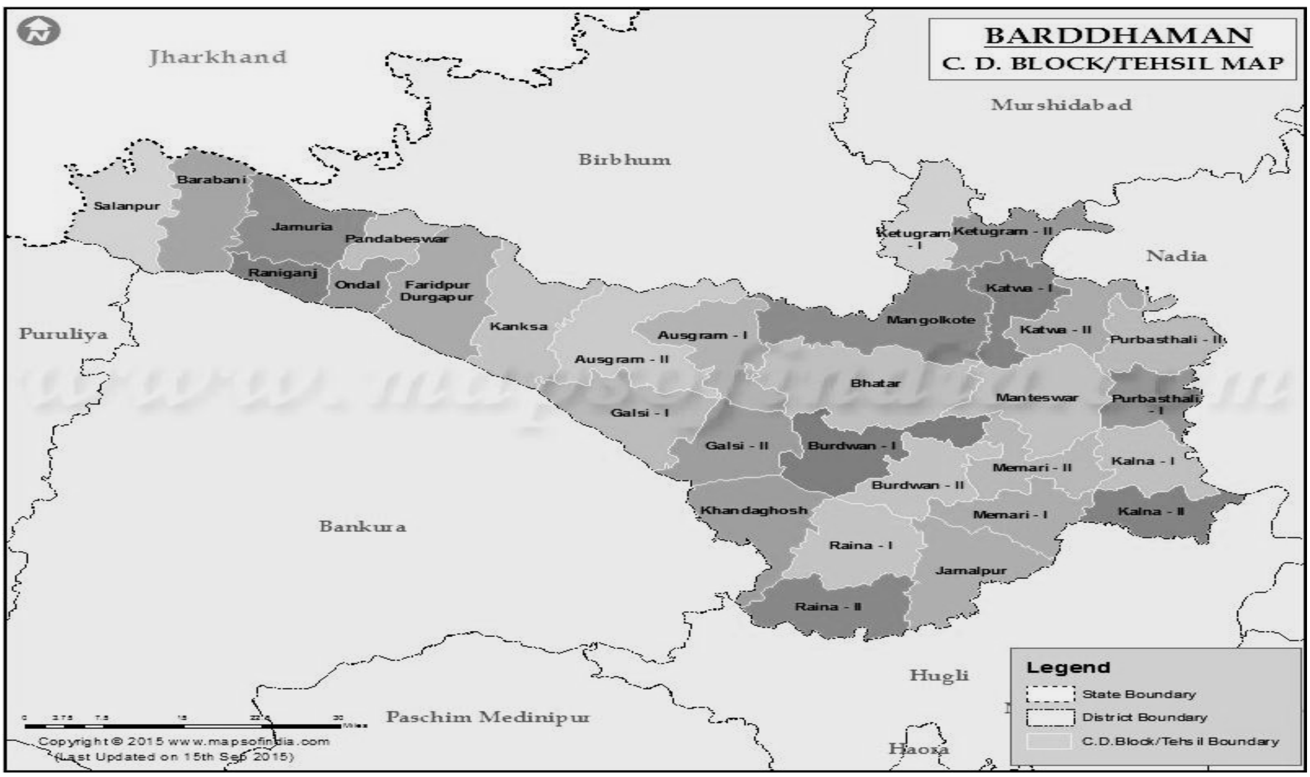
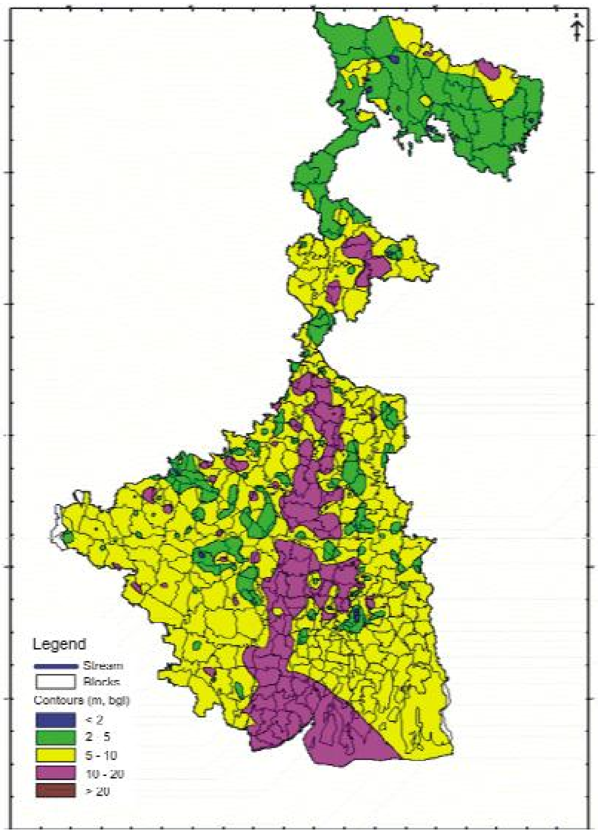
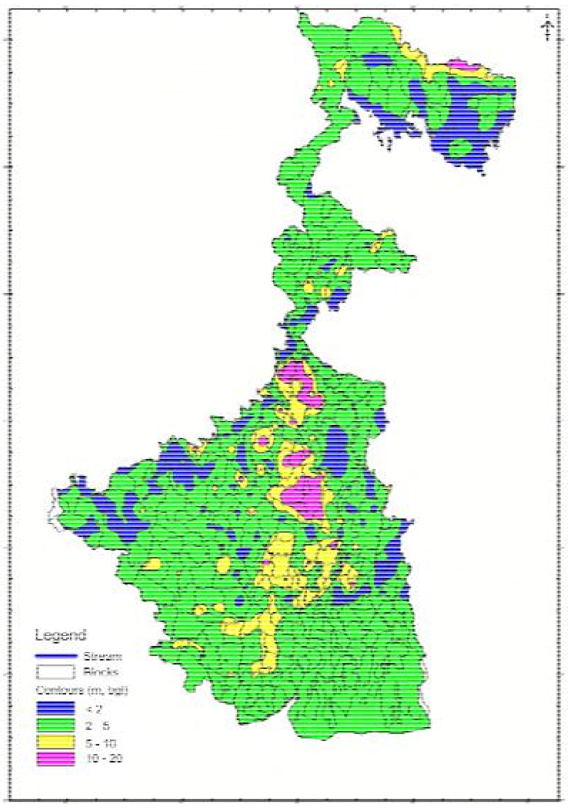


Figure 1. Map of Burdwan district



Source: Bhu-Jal news 2009

Figure 2A. Depth to Water Level Map – Pre-monsoon 2007



Source: Bhu-Jal news 2009

Figure 2B. Depth to Water Level Map –Post- monsoon 2007

Table 1 shows the average rainfall is this region is about 1496mm. The winter season starts from the middle of November and continues till the end of February. March to May is the dry summer season intervened by tropical cyclones and storms. June to September is the rainy season while October and middle November is autumn. Large areas are flooded during wet summer.

During pre-monsoon, 2007, major part of the state shows depth to water level ranging from 2 to 5 m (33%) and 5 to 10 m (45%) below ground level. A considerable area along Hasimara-Jaigaon section in northern part of Jalpaiguri district falling under "Bhabar" zone, deeper water level with maximum value of 11.75 m below ground level has been recorded. Comparatively, deeper water levels have also been recorded in "Barind" tract of Malda district (where maximum water level has been recorded to the tune of 14.70 m below ground level), western part of the river Bhagirathi in Murshidabad district, eastern part of Bardhaman district, western part of Hooghly, and a considerable area in West Medinipur districts. In the coastal tract of the State (South 24 Parganas, parts of E. Medinipur, Howrah, North 24 Parganas) the Piezometric surface mainly lies between 2.0-5.0 mbgl and 5.0-10.0 mbgl. However, in some parts of East Medinipur, the piezometric surface ranges from 10.0 to 20.0 mbgl. During post monsoon, 2007 the depth to water level, in general, ranges Bhagirathi river covering Murshidabad, Hooghly between 2 & 5 mbgl in major part of the state, except in 'Barind' tract of Malda district, 'Bhabar' zone of Jalpaiguri district and western part of the Bhagirathi river covering Murshidabad, Hugli, Birbhum districts and eastern part of Barddhaman district, underlain by older Alluvium formation, where deeper water level has been noticed. The pieizometric surface in parts of South 24-Parganas and coastal part of Medinipur and Haora districts ranges between 2 and 10 m below ground level. Ground water level scenario in West Bengal has also been depicted in the fig- 2 A & B.

A sample of 50 farmers from 6 blocks was selected randomly. Survey was mainly done on modified format by open ended interviews. Farmers selected their crops based on the land type, availability of irrigation water and on the local market demand. Rice (kharif and boro), mustard, jute, potato and onion are the major crops cultivated in the area. Farmers in this subdivision are dependent on rainfall and surface water during kharif season but have to depend on the groundwater during other seasons. All the 50 farmers were groundwater buyers and they used groundwater lifted by Electric Centrifugal (EC) power motive submersible pump of 5 hp with 3" diameter of delivery. Water level in all cases varied from 50 to 60 ft, and the average flow rate of the submersibles was 0.19 m^3/min i.e. 11.36 m^3 per hour.

Amount of water (m^3 / per hour) = Running hour x 11.36

Data collected in this study were normally distributed. A Pearson's chi-square model was followed to examine the variations among the crops in relation to land used for farming and also in relation to volume and cost of groundwater Paired t-test was used to examine the decision making differences between the woman participants of SHG and non-SHG households in relation to social, economic and institutional factors. A general linear model (GLM) was used to analyze the variations among the lands in relation to cropping pattern, crop economy and cost of cultivation, gross income analysis from crops. We conducted all statistical analyses using the software SPSS 20.0. Probability level for rejection of the null hypothesis was set at $p < 0.05$.

3. Results

3.1. Cropping Patterns

Cropping pattern for each Block under present situation is furnished in **Table 2**. A wide range of cropping patterns was found in the study area, but the major patterns are rice based. Potato, oilseeds, jute, onion are the major non-rice crops.

Table 2. Present cropping patterns in the study area

Block name	Cropping patterns
Katwa I	Kharif rice-Boro rice /Jute -Potato/Mustard/Onion
Katwa II	Kharif rice-Boro rice /Jute -Potato/Mustard/Onion
Ketugram I	Kharif rice-Boro rice/ Potato/Mustard
Ketugram II	Kharif rice-Boro rice/ Potato/Mustard/ Onion
Mongolkote	Kharif rice-Boro rice/ Potato/Mustard

The dominant food crop of Burdwan district is rice which accounts for about 62 percent of agricultural land use and the remaining 38 percent by jute, potato, mustard, onion etc. (**Fig. 3**). Although, the same land was used for more than one crop, a total of 160 ha land was selected for 6 types of crops with 27.00 ± 7.76 (mean ± S.E.). Farmers in West Bengal generally grow two or three crops and left their lands fallow during the rest of the time. Of all lands used for cultivation, 62% were used only for rice production showing that the farmers were engaged with the traditional rice farming (χ^2 = 5.76, df = 1, $P < 0.05$), and it is also applicable in Bangladesh (Haque et al., 2012). A total of 56.14 ha land was used for kharif rice and 11.20 ha land was used for potato production, and there were significant variations among the lands in relation to cultivation of crops (F = 51.484; df = 5, 299; P<0.0001).

3.2. Economics of Groundwater

Although, this subdivision is a rain-fed region, groundwater was used for every crop. A total of 253624.48m^3 groundwater was used for the cultivation of 160 ha lands. Maximum amount of 3407.40 m^3 groundwater per hectare was used for summer rice and a minimum amount of 319.04m^3 groundwater per hectare was used for jute (**Fig. 4**). Therefore, there were significant variations among the crops in relation to use of groundwater per hectare (F = 108.249; df = 5, 299; P<0.0001).

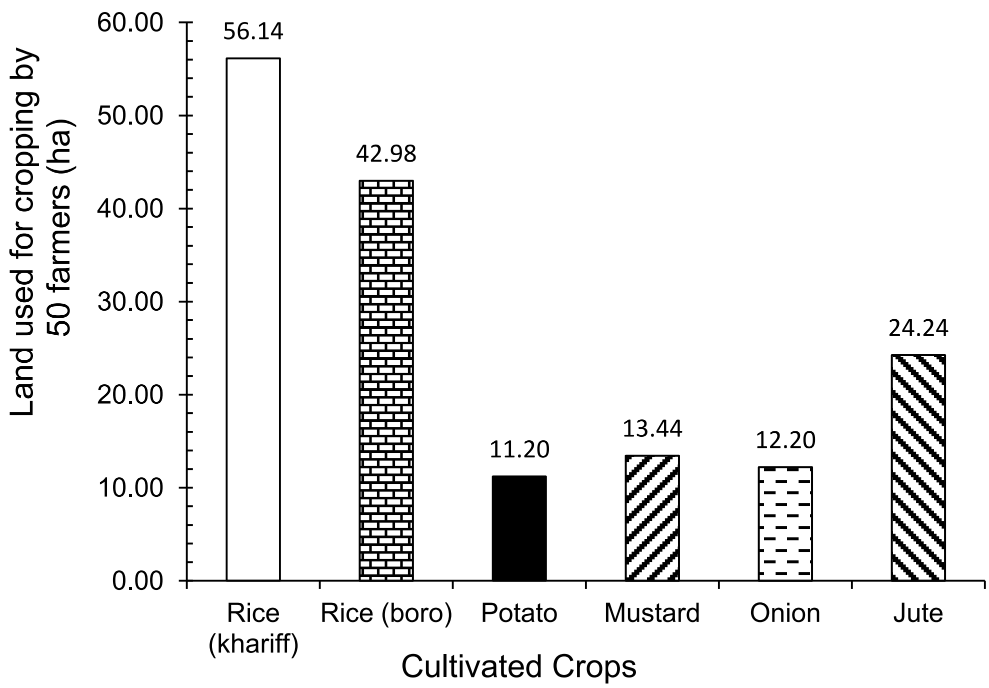


Figure 3. Land used for different cropping (ha) by 50 farmers

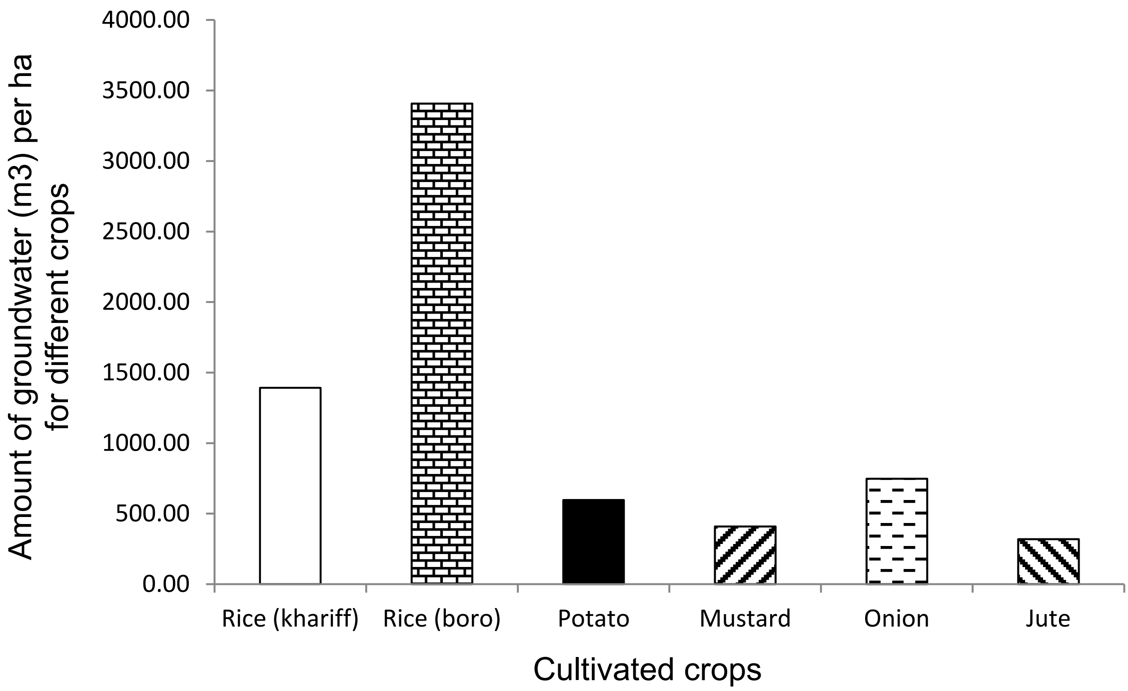


Figure 4. Crop wise volume of groundwater for 6 selected crops

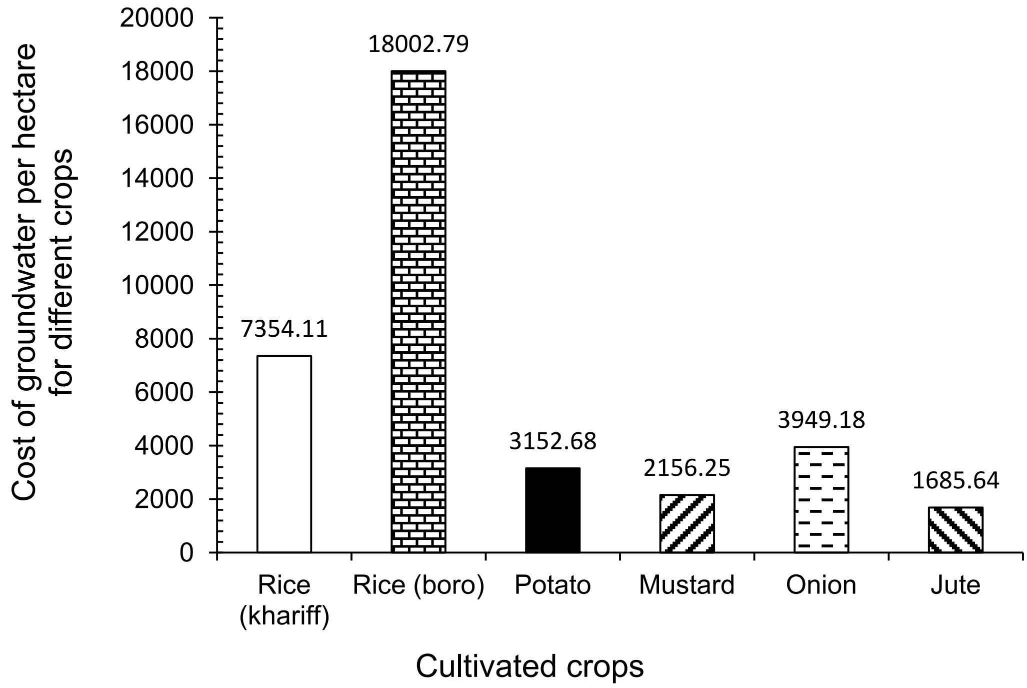


Figure 5. Cost of groundwater per hectare for different crops

West Bengal is well endowed with groundwater. Net annual groundwater availability is high (30.36 billion cubic meters) as is rainfall (1500-200 mm per year), yet its potential for development in many regions has not been reached. Only around 42% of the state's groundwater resources are being used because of policy restrictions and concerns over groundwater scarcity and quality. Historically, groundwater has played an important role in West Bengal's agriculture. In the late 1980s and early 1990s, agricultural growth rates were 6% per annum, which growth rates and this in turn can support poverty alleviation was attributed to expansion in the area under boro rice cultivation and an increase in yield of all paddy crops due to assured irrigation from tubewells. Carefully crafted groundwater policies could help the state return to these high agricultural growth rates and this in turn can support poverty alleviation.

In all cases, groundwater was lifted by submersible pumps. The cost of groundwater per hour was Rs. 60. The total running hour of submersibles was 22333.5 hour for 160ha land. Cost of groundwater per hectare was Rs. 18002.79 in the case of summer rice and the cost of groundwater per hectare was Rs. 1685.64 in the case of jute cultivation (**Fig. 5**). Therefore, cost of groundwater varied with the crops (F = 108.255; df = 5, 299; P<0.0001).

From this study it is evident that groundwater requirement of various crops are different. Volume as well as cost of groundwater was maximum in the case of boro rice and it was minimum in the case of jute ($\chi2$ = 5991.32, df = 5, P < 0.005, $\chi2$ = 31656.65, df = 5, P < 0.005 respectively). Due to expansion in the area under boro rice cultivation from late-1980s, the extraction technology started changing towards submersible pumps and the depth of wells increased to beyond 400 feet in many areas. Water extraction increased rapidly, under the influence of subsidies on electricity, lack of metering, credit availability, and the commercialization of agriculture (Singh 2003). This led to rapid declines in the water table, decline in the quality of water, increased frequency of well failure and rapidly rising costs of well investment and operation. This expansion of groundwater use has resulted in a speedy decline in the groundwater table in several parts of the country (Dhawan, 1995; Moench 1992; Bhatia, 1992).

However, farmers were interested to cultivate rice. Actually, farmers do not choose crops on the basis of water requirements, rather they choose crops based on water availability and estimated net returns. It was previously commented by Sarkar and Das (2014).

3.3. Crop Economy and Cost of Cultivation

Fig. 6 shows the production of each crop per hectare. Production per hectare was maximum of 230.93 qts in the case of potato and was a minimum of 14.61 qts in the case of mustard, and there significant yielding variations among the crops (F = 34.730; df = 5, 299; P<0.0001).

Total cost of cultivation of each crop was estimated by adding the water cost with other costs i.e., labour cost and fertilizer cost. Cost of cultivation per hectare was maximum of Rs. 117258.20 for onion and it was minimum of Rs. 24159.98 for jute (**Fig. 7**). Therefore, the cost of cultivation varied with the crops (F = 33.080; df = 5, 299; P<0.0001). Total cost of cultivation for each crop depends upon several factors such as volume of groundwater needed, market prices of fertilizers and labour costs (Pal, 2013) etc.

The prices of agricultural commodities are usually determined by market factors of demand and supply. If there are many farmers producing the same commodity then they will fetch a lesser price for their produce. If there is great demand from consumers for a certain commodity then farmers can expect to get a higher price. These prices keep changing daily. Other factors that determine the price of the product are its quality, yield and pest free status. Climatic conditions, international prices, cost of production and new laws may also affect the prices of agricultural commodities. The price at different markets may be different. The government has fixed minimum support prices for certain agricultural products. Farmers also have the option to sell their produce to private dealers if they stand to get a better profit.

The rate of production per hectare was comparative higher in the case of potato as well as in the case of onion. Therefore, earning per hectare was maximum in the case of onion (Rs. 169585.74/ha) as well as in the case of potato (Rs. 119757.14/ha), and so, earning per hectare varied with the crops.

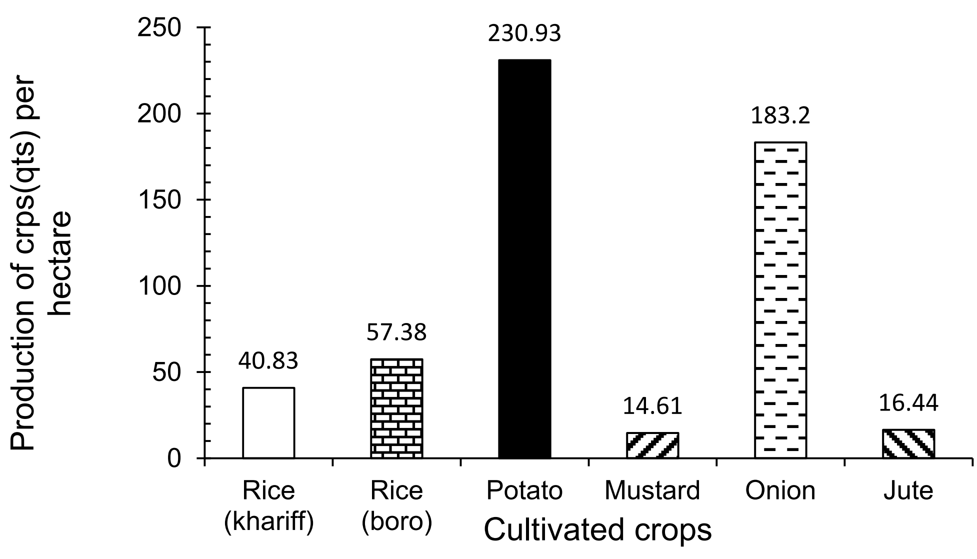


Figure 6. Production of crops (qts) per hectare

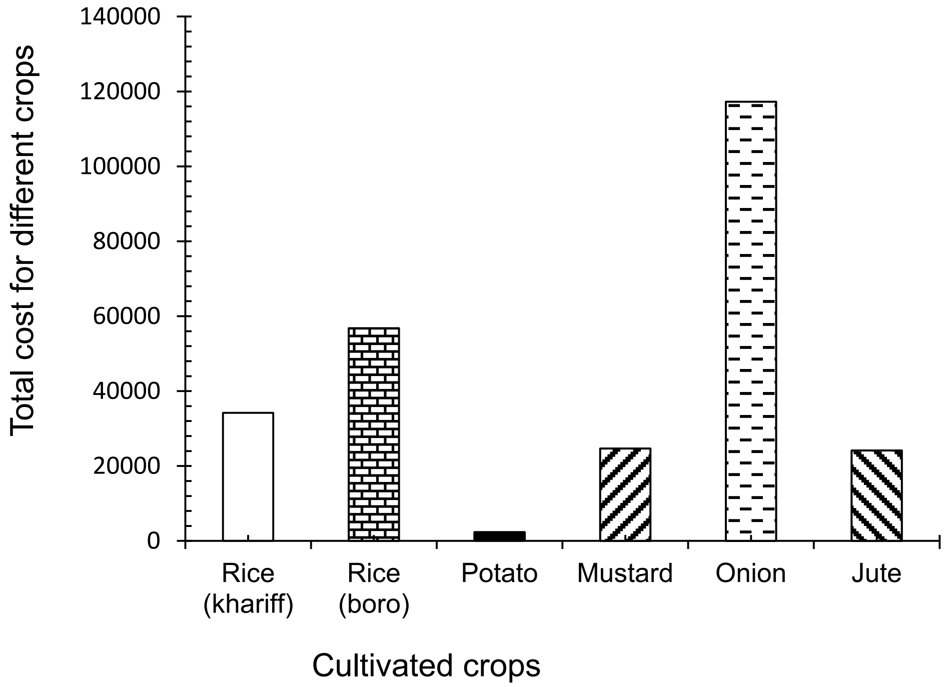


Figure 7. Cost of cultivation per hectare for each crop

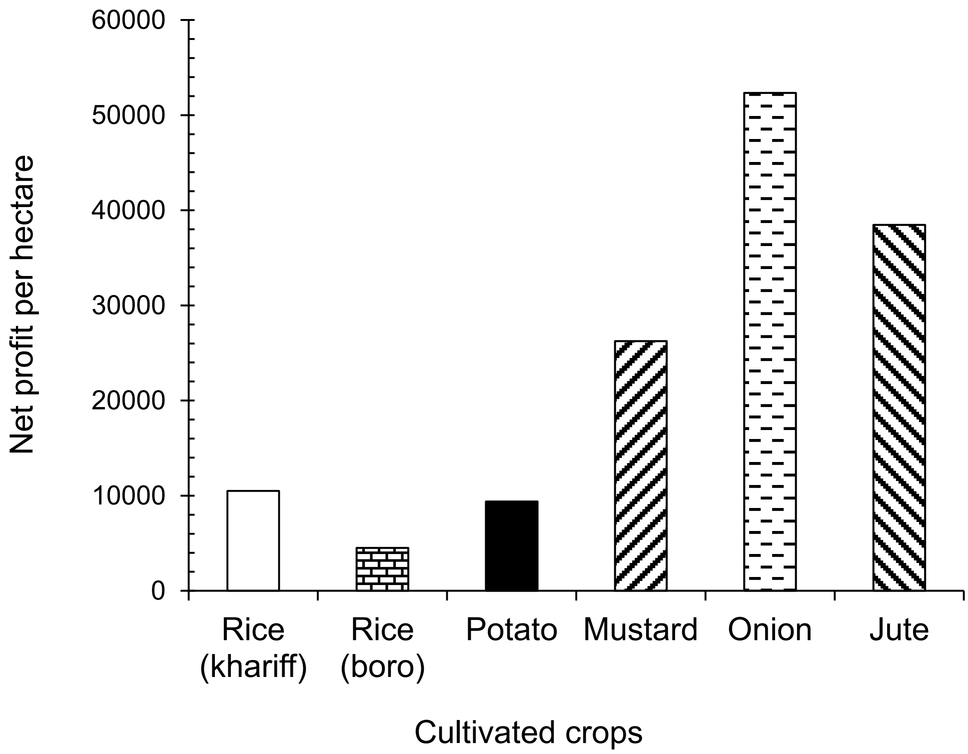


Figure 8. Amount of profit (Rs) per hectare

3.4. Gross Income Analysis from Crops

All the crops were considered for income analysis in this study. The gross income for water buyers was estimated from crop yield per acre multiplied by its unit price. Amount of profit per hectare was a maximum of Rs 52327.54 in the case of onion and was a minimum of Rs. 4502.05 in the case of summer rice (**Fig. 8**). Therefore, profit from cropping varied with crops (($F = 22.845$; df = 5, 299; $P<0.0001$).

4. Conclusions

West Bengal has a very little scope to increase agricultural production through expansion of land, as the cultivated land has remained constant and even decreased in many cases. The introduction of modern varieties of rice, wheat, oil seeds, potato and other crops has shortened the production cycles and increased cropping intensities and yield. In West Bengal rice production has been increased in 90's with the cultivation of boro rice. With the expansion of boro cultivation, electricity for operating pumps is becoming a major agricultural input, and cost on this account will increase due to the high price of electricity in the world market. The higher cost of engines, pumps and installation cost of the tube well along with higher operation cost will make it less economical. Groundwater overdraft can lead also to significant problems in both water quality and water availability; thus, excessive groundwater use is a critical policy issue in balancing water uses for food production and the environment. Moreover, excessive groundwater pumping can lead to the drying up of more shallow wells, requiring deeper tubewells, and increased pumping cost. As the depth to water increases, the water must be lifted higher to reach the land surface. If pumps are used to lift the water (as opposed to artesian wells), more energy is required to drive the pump. Using wells can thus become rohibitively expensive.

Contrary to the claim that rice cultivation is more profitable than alternative crops, this report has cited research showing that there are other alternatives such as mustard, potato, onion or jute which could yield higher returns than rice. In order to make these alternatives feasible for implementation, farmers will have to have access to agricultural inputs as well as irrigation water. The water requirements for rice are much greater than these alternative crops, thus making it extremely important that water resources are used in the most effective and efficient manner.

From this study, it may be suggested that to avoid the groundwater depletion and also to get higher returns, farmers should consider crop diversification. It should be recommended that although, rice is the main food in West Bengal a shift away from the rice-rice cropping pattern to rice-potato/onion/jute. In this context, it should be noted that crop diversification had been one of the suggestions to bring changes in Punjab's agriculture since 1986. Two Johl Committee reports (1986 and 2002) recommended a shift away from the wheat-rice cropping pattern to a wheat-maize one.

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