Structural changes of irrigation in Bangladesh: a synthesis of FGDs from 96 villages

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Abstract:

Groundwater irrigation through STW and DTW started mostly after 1970s. The main objectives in conducting this study and focus group discussions (FGDs) at 96 villages are to identify root level information regarding irrigation and its mode of payment. Irrigated land, especially rice land, has increased remarkably in Khulna and Rangpur divisions. There are plenty sources of clear water in the villages, however it has been observed that quality of water worsens over the period of time – from clear to cloudy and reddish color. Due to tremendous increase in numbers of STW, DTW command area decreases and command area under STW decreases with the significant increase in the number of machine owners. It implies the suitability of STW as farmers' friendly irrigation technology. Owners' land increases and buyers' land decreases, which indicate that more farmers have more opportunity to own STW. Irrigator farmers are shifting from crop share to fixed rate and two part tariff payment systems since it is economically viable for the buyers. Prices in fixed charge and two part tariff are changing over time. Using more water from underground, the depth of groundwater level is going down and problems on iron, arsenic and saline contamination are becoming a big issue in some areas. More than seventy percent farmers are taking credit from bank, money lenders and NGOs. Due to higher interest rates implemented by money lenders, farmers are getting more credit from NGOs now. In selling irrigation water, there arise some disputes due to have insufficient and irregular supply of water. Most of the disputes resolve in the village level - village council or people of the particular area resolve the problems and few of them come to legal court system. Division wise irrigation technology and efficient payment method and guidelines for price fixation of irrigation may help to reduce the use of groundwater. Observing these dramatic structural changes in water market, we are investigating the determinants of water price, contract choice and dispute resolution of groundwater irrigation.

Introduction:

Groundwater irrigation technologies i.e. mainly Shallow Tubewells (STWs) and Deep Tubewells (DTWs) play a crucial role in accelerating foodgrain production (mainly rice and wheat) in Bangladesh. In 80's and 90's, there has been a very rapid growth of groundwater irrigation for growing Boro paddy in the dry season. In 2010/2011, 1.55 million STWs accounted for around 80 percent of groundwater irrigation, 67 percent of the total area irrigated by groundwater and about 66 percent of total area irrigated in the dry season (BBS, 2010 and BER, 2010).

The market for irrigation technologies has been largely liberalized and privatized since early 80's. With the expansion of STW irrigation, a relatively competitive market for irrigation water

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has been evolved. The main characteristic of the market is that the STW owners irrigate their own land and partners' land[5] and sell excess water to irrigate plots of their neighbouring farmers not only for neighbouring interest but also for the their own benefits. Payment of irrigation water is made in cash per unit of land or as one-fourth crop-share or different mode of rental arrangements. As the irrigation water market is maturing with increased number of pumps installed, different pump owners to run their water selling business profitably pursue different strategies. One common aspect of the market is the sharing of STW enterprise by a few partners basically for raising capital for purchase and operation of equipments. It is not very common phenomenon but it is found in the farm levels.

In groundwater irrigation, the market is an example of impersonalization. It is very important to the relationship between seller and buyer of water for irrigation their crop. The seller and buyer may have kinship, relative, neighbor, same social group, etc. It is observed that the relationship is somehow very strong and it has durable continuation in the village level. In long run, buyer experienced some unanticipated behavior from the seller regarding normal irrigation in their crop fields. They usually resolve this sort of problem through personal communication with the help of other people from the same social group or village. It is very important to investigate whether this unexpected relationship between two groups creates inefficiency in crop production. It is also matter of investigation that which factors are more effectual to control the inefficiency issue.

It can be seen from the several studies (BBS, 2009; BER, 2009; Ali, 2010; DAE, 2011; Rahman, et al., 2011; Majumder, et al., 2011) that the number of irrigation technologies increased over the years in Bangladesh. It is also found that at the initial stage, the seller had monopoly to sell water to user. The payment system and rate they proposed were executed directly. The seller preference was stronger than user to determine the contract of irrigating land. Due to increase the number of irrigation technologies particularly the most popular STW, the preferences of buyers are becoming stronger. It is also seen that some tubewell owners are entering this market only for selling water as a business (Rahman, et al., 2011). They are caring more the preferences of the users.

[5] Ownership of a STW may have more than one person i.e. a group of farmers from same family kinship may buy a STW to irrigate their land together. They are treated as partner of that STW.

Water market:

Water market is the newly grown market all over the world. Getting recognition of irrigation as leading input, the water market has become the focal point of discussion. According to Shah (1989) the term "Water market" has been used to describe a localized village level informal arrangement through which owners of modern wells sell irrigation service to other members of the community. It is also noted that once the owner finishes irrigating his/her own plot, it is to his/her advantage to sell the water to as many buyers as possible, as long as s/he can cover costs (Kajisa, et al., 2005; Shah, 1993). The term water market is a euphemism. Water may be lifted from open or tubewells, deep or shallow wells or from cannels, tank, river, drains or such other surface sources. It may be transported to the buyers' field either through unlined field channels or through underground pipeline networks. Where land holding are fragmented, most sellers of water are also buyers of water from other owners. Most farmers sink wells in one or two of their largest and the best fragments and often use purchased water for irrigating their own fields and also sell water to other farmers under various payment systems. Markets started as natural oligopolies but irrigation equipment market and support services are compatible leads to increasing the degree of competition.

According to Tsegabirhan, W. (2004), there are a number of specific characteristics of water that inhibit the smooth operation of water market.

Moreover, quantification devices and transferring mechanisms, which increases the investment cost, must be constructed to ensure market exchange in irrigation water. Even if these devices are constructed, they may not be sufficient to achieve a full-fledged market system. In this regard there is a basic problem of choosing the correct measure for levying water charges. Should one take the applied water or the effectively utilized volume of water in a given field of cultivable land to measure the volume of water consumed by a plot? The problem arises because there exists a significant difference between applied volume of water and actually used water in the designated field, attributed to water losses due to evaporation and seepage through out the water route. The importance of these variables is directly related to distance of an irrigated plot of land from the source of water, the type of canals, as well as the over all climatic conditions of the

area. So, to understand the water market clearly, it is necessary to know the actors who play vital roles in supplying and taking irrigation water.

Progressive Irrigation Development in Bangladesh

Up to the 1950s, Bangladesh (formerly East Pakistan, and even earlier, part of greater India) was dependent on traditional means of irrigation only, such as swing baskets, doans, etc. Modern tubewell irrigation technology was first introduced here in the early 1960s. The dependence of Bangladesh's agriculture on the south-west monsoon and its consequent vulnerability has been recognized from the earliest times. In Bangladesh, the strategy for economic development during the early 1950s was focused on large-scale public projects undertaken to stabilize water regimes associated with rainy season rice irrigations. Investments then took two main forms: improvement of flood control and drainage, and development of supplemental irrigation during the monsoon season. This approach was institutionalized in 1959 with the creation of the East Pakistan Water and Power Development Authority (now Bangladesh Water Development Board, BWDB) and the development of the nation's first Water Resources Master Plan in 1964 (Sattar, 1999).

Although the major emphasis was on flood control projects, small scale surface irrigation systems were tried out during the1960s. About 4,000 low lift pumps (LLP) were installed by the East Pakistan Agricultural Development Corporation (now "Bangladesh Agricultural Development Corporation," BADC) by 1967 (EPADC, 1968). Programs to tap the subsurface water commenced in 1961 with the installation of about 400 deep tube-wells. Under the guidance of World Bank, an action plan focusing on food production, not flood protection, through small and quick yielding irrigation schemes was undertaken in 1972 (IBRD, 1972). The new plan suggested a modest increase in large gravity projects, rapid growth in tube-well development, and constrained development of LLPs is limited. The expansion of LLPs was limited by the supply of dry-season surface water. Several large and small-scale development projects related to flood control, drainage, and irrigation were implemented by BWDD. The government's main strategy for economic development during the second and third five-year plans was to undertake

short-gestation, low capital, and quick yielding projects. This lead to a massive expansion in the tube-well programs, and by 1985, 17,000 DTW and 156,000 STW were in operation. The number increased to 24,059 DTWs and 348,875 STWs by the end of 1992–1993 (BBS, 2001). This massive as well as rapid expansion of the tube-well program has led to overdraft of groundwater in some areas of the country (especially in the north-western, Rajshahi region). The number increased to 27,117 DTWs and 1,128,991 STWs in 2005 (BADC, 2005) and 32,174 DTWs and 1,374,548 STWs in 2008 (BADC, 2008).

Groundwater irrigation market in Bangladesh

With increasing awareness of the need to improve irrigation efficiency for boro rice production, screening of plots" by the suppliers and users of irrigation water is under way in intensively developed areas. Screening is influenced by the social, economic, and political relationships between water sellers and water buyers and by the agronomic and soil characteristics of the irrigable plots. For example, water sellers try to reduce conveyance and seepage losses by avoiding plots that are distant or have poor soils and topography. Water buyers also choose among water sellers, depending on the distance of plots to water sources, contract terms and payment requirements, and other social and economic reasons. Such market signals lead to the continual adjustment of command areas. One implication of such adjustments and negotiations is that inefficient tube well command areas are being squeezed by the more efficient ones and, in many competitive areas, less efficient and derelict deep tube wells are losing plots to newly installed shallow tube wells that disregard government spacing regulations. The problem of drawdown externality has arisen in some districts. In years of insufficient rainfall, the problem becomes so acute that shallow tube wells and hand tube wells give low discharge and often run dry, although for only a short time (Gill 1983).

Finally, competition in many areas has pushed down prices for water from one−third crop share a few years ago, to one−fourth or even one−fifth crop share in recent years (BAU 1986). The threat of encroachment or forces of competition caused water suppliers to revert to a cash payment system from a share payment system or to resist a shift from the cash payment system to the share payment system (Mandal, 1993).

Mode of existing payment systems for irrigation water:

The major factors significantly related to the performance of Deep and Shallow tubewells were the systems of payment of water. As the irrigation water market is maturing with increased number of pumps installed, different pump owners pursue different strategies to run their water selling business profitably. Payment of irrigation water is made in cash per unit of land or as one-fourth crop-share or different mode of rental arrangements. There are generally two major forms of payments for water under DTW and STW: i. crop share payment and ii. Cash payment. Initially share or fixed cash payment were dependent on whether the machine is operated by diesel or electricity. Fixed cash payment was usually found if it was operated by electricity. Crop share payment was usually used for the diesel operated machine. In share payment system, owner of the tubewell supply water to the user's plot for the whole irrigation season and gets 25 per cent share of the harvested crops. In this share system, STW owners collect their share from the land after harvesting crop i.e. HYV Boro. (If they irrigate well, they will receive good share and it also depends on users' practice of weeding, seedlings, use sufficient fertilizer and insecticides. Yield also depends on rainfall, flood, high speed winding in the flowering stage, etc.).

Table 1. Existing contracts in irrigation water market

Sl. No.	Operating system	Mode of payment	Rate of payment	Timing of payment	Price range	Input provider	Popularity	Trend
1.	Diesel	Crop	¼ share of harvest	After harvest	18000-25000	Seller	Popular	Old
2.	Diesel	Cash	Fixed/ha/ season	Beginning the season	15000-18000	Seller	Not so popular	Emerging
3.	Diesel	Cash	Fixed/ha/ season	Beginning the season	12000-13000	Buyer	Most popular	Most emerging
4.	Electricity	Cash	Fixed/ha/ season	Beginning the season	14000-16000	Seller	Popular	Emerging
5.	Electricity	Crop	¼ share of harvest	After harvest	18000-25000	Seller	Not so popular	Old

Source: Rahman, et al., 2011

Fixed cash payment per unit of land time is usually determined approximately based on the average cost of supplying water including fuel, management and supervision. Payment is made partly at the beginning and partly after the harvest of paddy. Cash payment system is basically two types: One is STW owner serves water whole season and how much cash an owner will get, depends on local arrangement between owner and user, time of payment, soil type and elevation of the plot, distance from the STW, relation with owner, etc. Another cash payment type is newly introduced cash payment system. In this system, users pay service charge for using shallow tubewell and use diesel and other irrigation management of his own. The service charge varies depending on location and contract between owners and users. There was crop share system before introducing this cash payment system. This payment system emerged due to high price of diesel and engine oil, failure of owners' commitment and user has some more availability of cash flow. The STW owners' take less responsibility in this system and can reduce transaction cost (Rahman, et al., 2011). Kei Kajisa et al. (2005) found 3 types of contracts in India: fixed charge per season, flat charge per application of water, and output sharing contracts. Under a fixed charge contract, water buyers pay a fixed amount of cash once per season for specified irrigation acreage for the entire season. Under a flat charge contract, a buyer irrigates as much as he wants at a given price per acre and pays each time he applies the water. By contrast, under an output sharing contract, the buyer pays for the water for a dry season crop by providing a certain portion of their product after the harvest of that crop.

Methodology:

In this study, 96 villages are chosen from 5 divisions of Bangladesh to get the perceptions of irrigation payment methods in different parts of the country. It covers 31 districts and 48 upazilas, where eight villages are selected from Village Dynamics of South Asia (VDSA) project areas. The main objectives in conducting focus group discussions (FGDs) at 96 villages are to identify root level information regarding irrigation and its mode of payment. The major topics of discussion at village level includes: road conditions, market communication, infrastructures (like school, madrasa, temple, etc.), socio demographic and socio-economic indicators of farmers (like education, occupation, family size, farm size, asset, income, etc.), access to credit facilities, availability of modern inputs, occurrence of natural calamities, exposure to seasonal stresses, availability of irrigation equipment, scarcity of irrigation water, depth of groundwater level, high prices of diesel and electricity, low price of farmers main outputs, and problems between water

seller and buyers of irrigation water and its probable solutions. Around 6 to 12 persons participated at each FGD. FGD participants are basically school teacher, village leader, knowledgeable person of the village, tubewell owners and users, rice growers, labourers and progressive farmers. In some cases, women are included as to share their opinions. The answers and statements are synthesized in this section.

Results and discussion:

Socio demographic and economic characteristics of villagers

Occupation

The socio-demographic characteristic, like the involvement in the different sectors of the economy, of the villagers in the study areas was also analyzed. Figure 3 and Figure 4 show this involvement of villagers in the different occupations of the economy for 2013 and 2003. In 2003, as shown in Figure 4, on the average, most of the villagers are involved in agricultural sector. Services sector ranked 2nd, followed by the business sector. However, it is also observed that there are a considerable percentage of the villagers who are unemployed. On the average, the percentage of the villagers who are unemployed is even larger than the percentage of villagers who are engaged in the business and service sectors combined. The same is also observed in 2013 as shown in Figure 3.It is also noticeable that percentage of people involved in agriculture sectors has been reducing in each division. On the other hand percentage of people involved in business and service sector has been increased significantly over the years (Table 2).

Table 2. Villagers' involvement in different occupation in 2003 and 2013 (in percent)

Division name	Villagers involvement in 2013				Villagers involvement in 2003				Change			
	Agri	Bus	Ser	Unem	Agri	Bus	Ser	Unem	Agri	Bus	Ser	Unem
Chittagong	63	7	21	9	74	4	11	11	-15	75	91	-18
Dhaka	74	8	8	10	79	4	5	12	-6	100	60	-17
Khulna	72	8	6	14	77	5	4	14	-6	60	50	0
Rajshahi	74	5	7	14	77	3	4	16	-4	67	75	-13
Rangpur	71	6	7	16	75	3	3	19	-5	100	133	-16
All	72	7	8	13	77	4	4	15	-6	75	100	-13

Source: Field survey, 2013

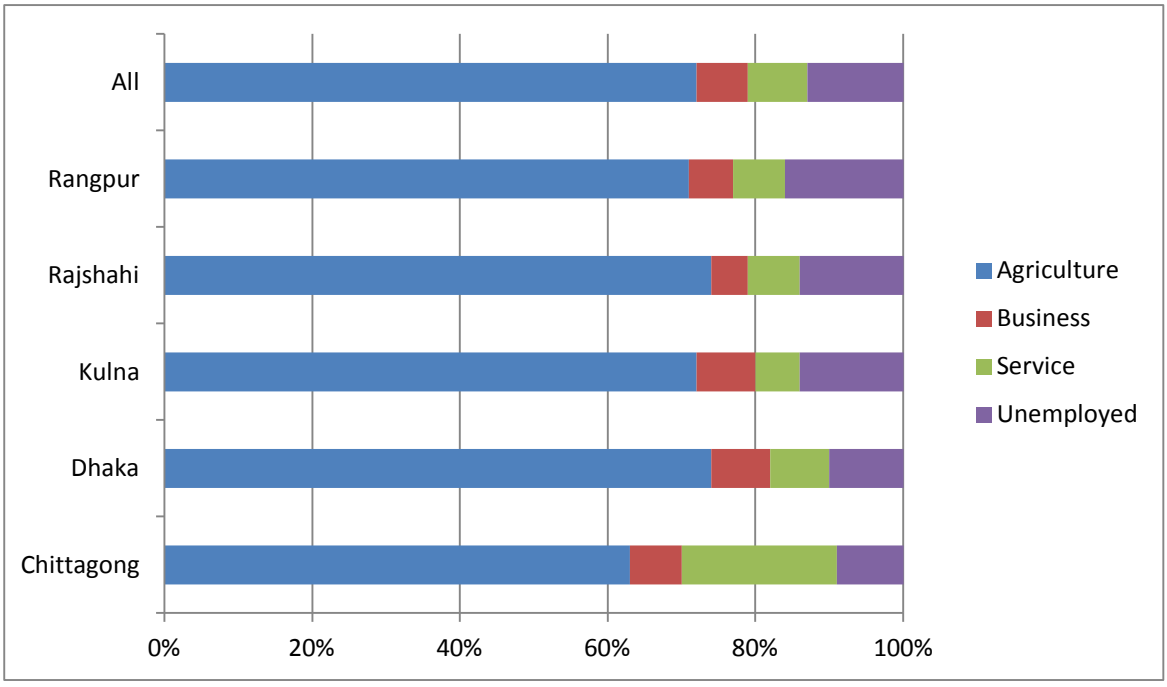


Figure 1. Involvement of Villagers in the different sectors of the economy, 2013

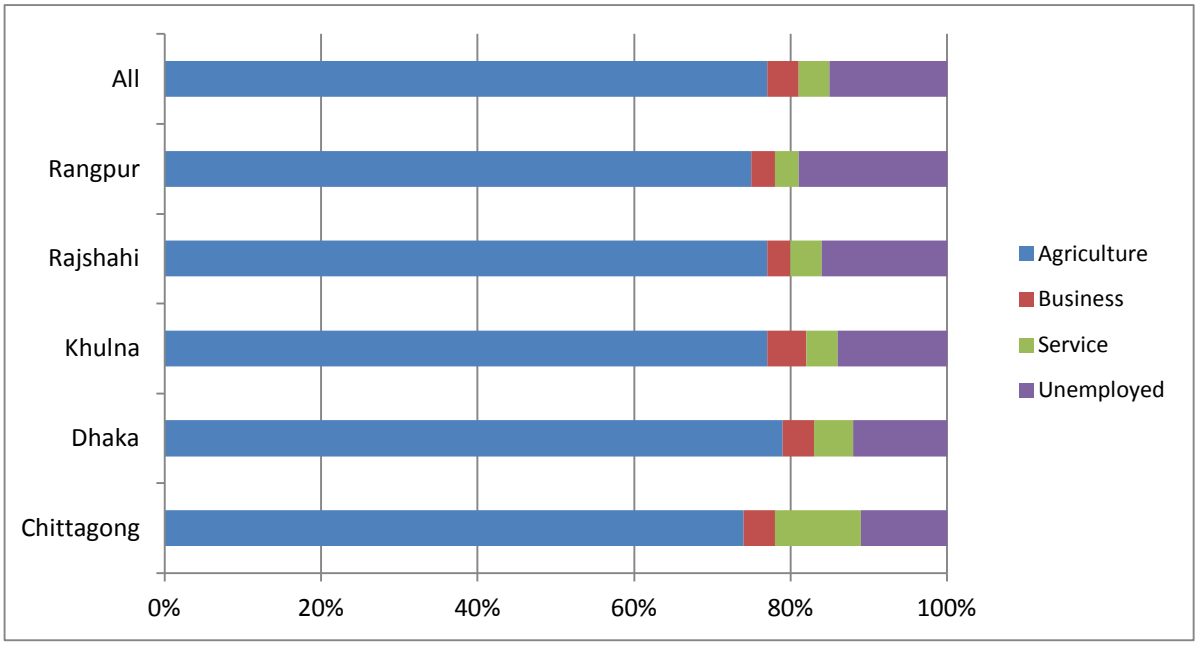


Figure 2. Involvement of villagers in the different sectors of the economy in 2003

Farm and non-farm activities

Table 5 shows that changes are there in wage labour and farm activities in 2013 compared to 2003. Here reduction of wage labour is significant but not own farm activities because most of the villagers are somehow engaged in farm activities. Women involvement in home and outside works follow the same patterns almost all the divisions.

Table 3. Farm and non-farm activities of the villagers in the study areas (in percent)

Division	2013				2003			
	Wage labour	Own farm activities	Housewife	Outside work	Wage labour	Own farm activities	Housewife	Outside work
Chittagong	42.50	57.50	96.00	4.00	50.00	50.00	97.50	2.50
Dhaka	19.14	70.68	93.64	6.00	29.46	63.21	97.14	2.857
Khulna	32.00	59.25	94.65	5.00	37.50	58.25	98.35	1.65
Rajshahi	36.36	50.00	90.23	10.00	45.00	46.14	91.54	8.45
Rangpur	32.18	51.14	89.36	11.00	35.45	52.95	96.59	3.41
Total	29.73**	58.53	92.19*	7.81*	36.93	55.36	96.00	4.00

Source: Field survey, 2013 ** & *Significant at 5 & 10 percent level of significance

Land characteristics

The pieces of land in the study areas are categorized as high land, medium land, and low land. Around 50 percent of the total land areas are, on the average, medium land area. While 24 percent are low land area and 21 percent are high land area.

Table 4. Village-wise land type in the study areas (Figures in percent)

Division name	High land area	Medium land area	Low land area
Chittagong	18.75	55.00	26.25
Dhaka	24.89	50.46	24.64
Khulna	27.50	46.75	25.75
Rajshahi	16.45	53.64	29.91
Rangpur	17.14	64.68	18.18
Total	21.47	53.87	24.67

Source: Field survey, 2013

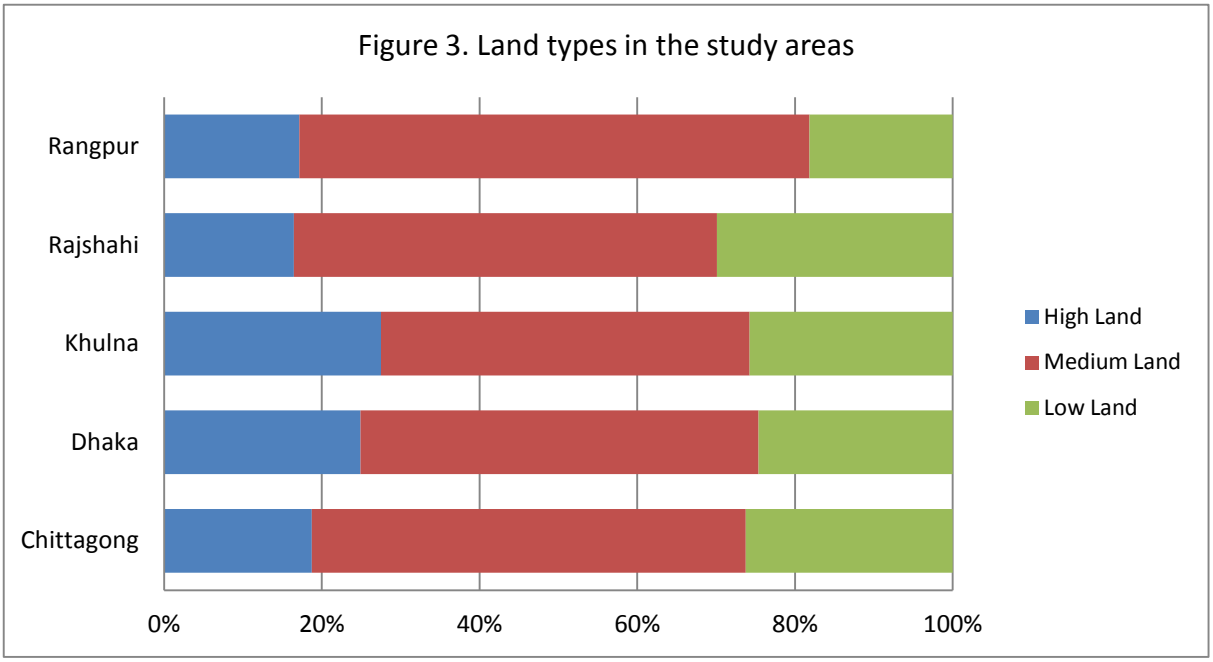


Table 4 shows the arable land increases 5 percent over last 10 years. Irrigated land increases more (13 percent) than arable (5 percent) and irrigated rice land (7 percent). Arable land increases more in Dhaka division (9 percent) than other divisions but irrigated rice land increase in Khulna division (18 percent) than any other divisions. It is also seen that irrigated rice area increases at 10 percent which is the highest among the five divisions. It means that irrigated area and irrigated rice land area are growing faster to meet up the food requirement of the country. The availability of modern inputs, information of those, awareness, etc. are the reasons behind this.

Table 5. Pattern of arable land, irrigated land and irrigated rice land in 2003 and 2013

Division	Figures in 2013			Figures in 2003			Percent change over 10 years		
	Arable land	Irrigated land	Irrigated rice land	Arable land	Irrigated land	Irrigated rice land	Arable land	Irrigated land	Irrigated rice land
Chittagong	95.00	64.50	62.00	92.00	63.75	62.50	3	1	-1
Dhaka	90.79	78.39	74.36	82.00	65.00	66.54	9	13	8
Khulna	93.95	91.30	65.5	92.00	73.50	63.00	2	18	3
Rajshahi	97.82	90.68	74.91	93.00	80.91	67.73	5	10	7
Rangpur	93.05	87.73	69.32	88.00	73.41	58.95	5	14	10
All	93.75	85.46	70.97	88.00	72.29	64.17	5	13	7

Source: Field survey, 2013

Table 5 summarizes the characteristics of the soil in the study areas. The soil is characterized by color (red and black), type (sand, loam, clay), and quality (alkaline, saline). On the average, the soil from the study areas is black (91.88 percent, mostly loam (48.96 percent), and of alkaline quality (5.16 percent).

Table 6. Characteristics of soil in the study areas (in percent)

Division name	Soil color		Soil type			Soil quality	
	Red	Black	Sand	Loam	Clay	Alkaline	Saline
Chittagong	0.00	100.00	25.00	56.25	18.75	1.75	26.25
Dhaka	13.57	86.43	30.36	50.00	19.64	8.96	0.18
Khulna	1.00	99.00	29.00	44.00	27.00	5.00	1.00
Rajshahi	7.73	92.27	17.96	46.59	35.46	2.64	0.82
Rangpur	9.55	90.46	27.73	53.18	19.09	3.59	0.36
Total	8.13	91.88	26.41	48.96	24.64	5.16	1.63

Source: Field survey, 2013

Availability of irrigation equipments

Table 9 shows the number of irrigation equipment by type (STW, DTW, LLP) in the villages of selected divisions in the country, comparing 2003 and 2013. Among the three irrigation equipments, STW registered the biggest increase in use (9 percent per year). On the average, the use of DTW didn't change in 2013 compared to 2003 while there has been a decrease in the use of LLP considering the said period.

Table 7. Number of irrigation equipments by type in the selected divisions in 2003 and 2013

Division name	Equipment (No.)	2013	2003	Growth Rate (%)	Annual Growth Rate (%)
Chittagong	STW	20	8	150	15
	DTW	1	0	0	0
	LLP	0	0	0	0
Dhaka	STW	34	17	100	10
	DTW	1	1	0	0
	LLP	1	1	0	0
Khulna	STW	82	36	128	13
	DTW	1	1	0	0
	LLP	0	1	-100	-10
Rajshahi	STW	49	36	36	4
	DTW	2	1	100	10
	LLP	0	1	-100	-10
Rangpur	STW	65	28	132	13
	DTW	1	0	0	0
	LLP	5	14	-64	-6
All	STW	54	28	93	9
	DTW	1	1	0	0
	LLP	1	4	-75	-8

Source: Field survey, 2013

Table 8 shows the command area of the different irrigation equipments in the five divisions of Bangladesh. Among the three equipments, DTW has the largest command area in terms of decimal, and then STW comes second. However, the command area of LLP is very small compared to the other two equipments. Data also shows, on the average, that the command area for each irrigation equipment has decreased in 2013 compared to 2003.

Table 8. Command area (in Decimal) under different irrigated equipment in selected divisions in 2003 and 2013

Division name	Equipment (No.)	2013	2003	Growth Rate	Annual Growth Rate
Chittagong	STW	735	1370	-46	-5
	DTW	1200	5200	-77	-8
	LLP	0	0	0	0
Dhaka	STW	813	1212	-33	-3
	DTW	3075	5404	-43	-4
	LLP	5	12	-58	-6
Khulna	STW	357	607	-41	-4
	DTW	2967	3316	-11	-1
	LLP	0	27	-100	-10
Rajshahi	STW	457	816	-44	-4
	DTW	4120	5845	-30	-3
	LLP	33	18	83	8
Rangpur	STW	517	806	-36	-4
	DTW	3984	5493	0	0
	LLP	22	21	5	0
All	STW	580	931	-38	-4
	DTW	3582	5069	-29	-3
	LLP	14	19	-26	-3

Source: Field survey, 2013

Table 9 and figure 4 shows that number of shallow tubewell (STW) increase almost twice in 2013 than 2003. The increasing rate of STW number at Khulna division is the highest. On the other hand command area under STW decreases from 905 decimals in 2003 to 564 decimals in 2013 (Figure 5). It implies that increasing number of STW occupies the areas of early established STW. It is due to the cheaper and smaller type of STW machine.

Table 9. Village-wise number and command area of STW in 2013 and 2003

Division name	No. Of STW		CA of STW (Dec.)	
	2013	2003	2013	2003
Chittagong	20	12	735	1370
Dhaka	34	17	806	1212
Khulna	82	36	357	607
Rajshahi	49	36	457	816
Rangpur	65	28	517	805
Total	54***	28	564*	905

Source: Field survey, 2013 *** & *Significant at 1 and 10 percent level of significance

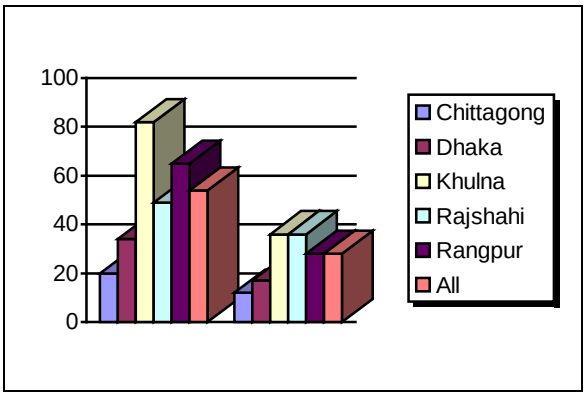


Figure 4. Number of STW in 2013 and 2003

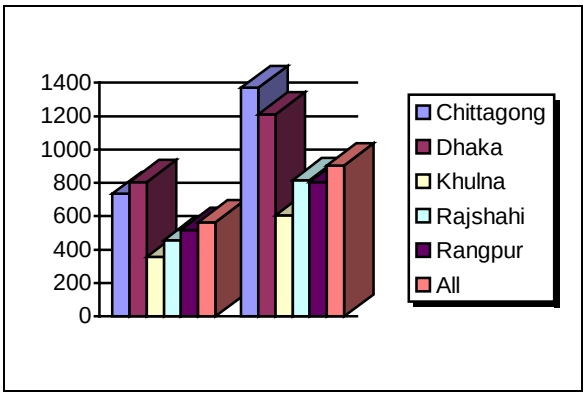


Figure 5. STW command areas in 2013 and 2003

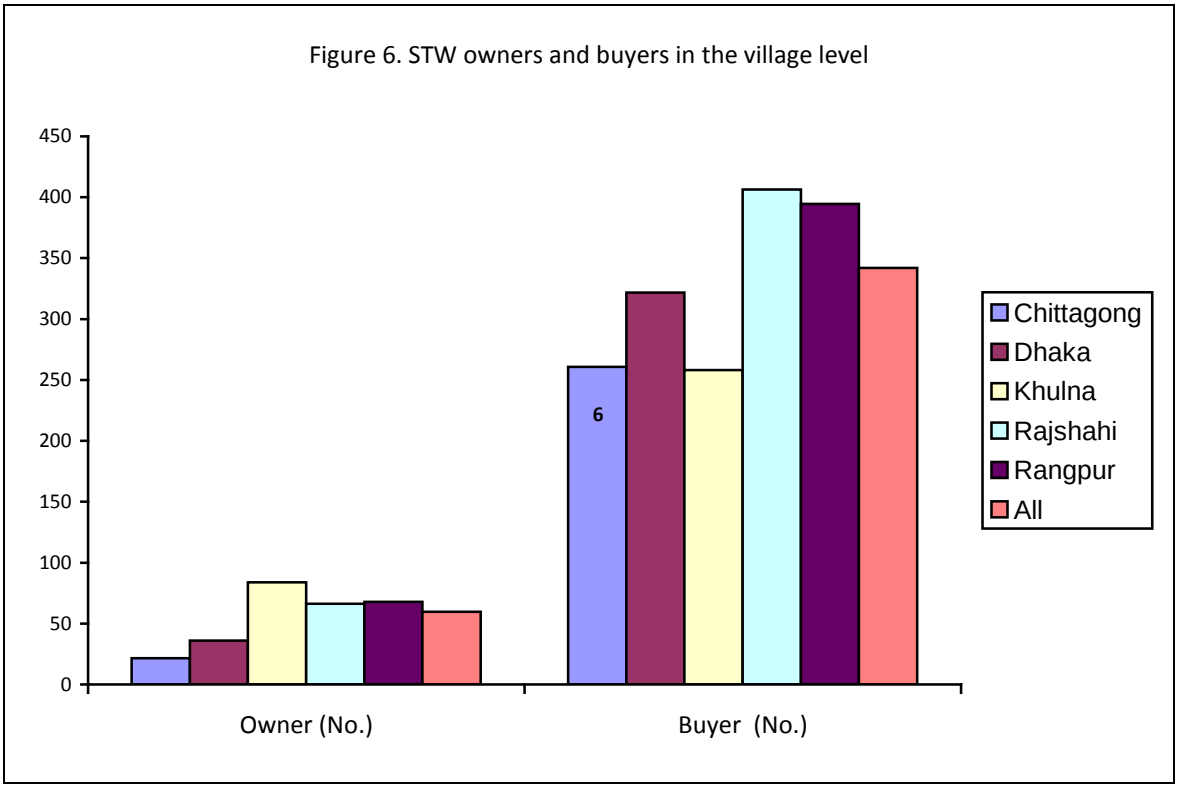
In this Table 10, number of STW owners and buyers are mentioned in every village by divisions. It can be seen in every village of all divisions, number of STW owners are less than buyers. On an average, number of owners in a village are 60 and number of buyers are 342 i.e. one STW owner supplies irrigation water to 6 buyers. This table also explains the owner and buyers' education levels. It is seen that owner and buyers' education level are similar but owners have little bit higher education level that buyers. Farmers of the study areas use alternative wetting and drying (AWD) method for irrigating their land. Twenty five percent farmers have heard and use AWD in Dhaka division but the percentages are very low in other divisions. It is implied that AWD information is not available to the farmers. When the perforated pipe was shown and explained its utility in irrigation, the farmers were very interested about it because the AWD technology may reduce the diesel or electricity cost and it may reduce the use of fertilizer also.

The farmers are asking more about it say, what will be the possibility of growing weed in their fields, will it require more water if the land dry more, etc.

Table 10. Village-wise number of irrigator farmers in the study areas

Division name	No. of owner (No.)	No. of buyer (No.)	Buyers per tubewell	Owner education (Class level)	Buyer education (Class level)	No. of AWD user (%)
Chittagong	21.50	260.75	20.88	6.00	6.00	0.00
Dhaka	36.07	321.71	12.85	5.79	5.18	24.64
Khulna	83.85	258.00	5.35	6.10	5.20	1.20
Rajshahi	66.27	406.32	9.89	5.05	5.23	4.32
Rangpur	67.86	394.41	9.49	5.86	4.41	5.77
All	59.63	341.95	10.17	5.71	5.05	9.75

Source: Field survey, 2013



The STW command areas are either shared by the owners or the users. From 2003 until 2013, the share of users in the STW command area is bigger than that of the owner's. However, the difference between the two has been decreasing. There has been an observed negative change in the share to land of users.

Table 11. Village-wise percentage share of owner and users' land in a STW command area

Division name	Percent share in 2013		Percent share in 2003		Growth Rate	
	Owners	Buyers	Owners	Buyers	Owners	Buyers
Chittagong	20	80	21	79	-5	1
Dhaka	40	60	29	71	38	13
Khulna	46	54	26	74	77	-27
Rajshahi	30	70	29	71	3	-1
Rangpur	44	56	29	71	52	-21
All	39	61	28	72	39	-15

Source: Field survey, 2013

Mode of payment for irrigation facilities

There are three types of payment for the irrigation water found in Bangladesh: fixed charge, output sharing, and two-part tariff. In 2003, it was observed that, on the average, the most (40.37 percent) of the divisions are using fixed charge as the means of payment. Thirty three percent of the contracts are using two-part tariff and then 26.61 percent used output sharing or crop sharing. It was only in Dhaka (36.67 percent) and Rajshahi (48.15 percent) that they rely more on output sharing. Almost the same was also observed in 2013 but fixed charge contract was higher than in 2003. On the average, around forty nine percent of the contracts are based on fixed charge, 32.28 percent are two part tariff, while the remaining 18.11 percent are output sharing. This same payment arrangement was also observed nearby villages. This mode of payment for irrigation water is summarized in Table 14. Shifting from crop share to fixed charge is higher in all divisions and it means crop share payment system is somehow not appreciable to the rice growers.

Table 12. Types of Contracts are using currently for the payment of irrigation water (Percent)

Division name	2013			2003			Nearby*		
	Fixed charge	Crop share	Two part tariff	Fixed charge	Crop share	Two part tariff	Fixed charge	Crop share	Two part tariff
Chittagong	4 (80.00)	0 (0)	1 (20.00)	3 (75.00)	0 (0)	1 (25.00)	4 (80.00)	0 (0)	1 (20.00)
Dhaka	14 (38.89)	9 (25.00)	13 (36.11)	8 (26.66)	11 (36.67)	11 (36.67)	14 (37.84)	9 (24.32)	14 (37.84)
Khulna	14 (58.33)	2 (8.33)	8 (33.34)	12 (60.00)	3 (15.00)	5 (25.00)	15 (60.00)	2 (8.00)	8 (32.00)
Rajshahi	15 (51.72)	12 (41.38)	2 (6.90)	11 (40.74)	13 (48.15)	3 (11.11)	14 (46.67)	12 (40.00)	4 (13.33)
Rangpur	16 (48.48)	0 (0)	17 (51.52)	10 (35.72)	2 (7.14)	16 (57.14)	17 (48.57)	1 (2.86)	17 (48.57)
All	63 (49.61)	23 (18.11)	41 (32.28)	44 (40.37)	29 (26.61)	36 (33.02)	64 (48.48)	24 (18.18)	44 (33.32)

Source: Field survey, 2013 *Existing contract of the adjacent village in 2013

The payment of irrigation water is through fixed payment and percent of crop sharing. Fixed payment accounts for 77 percent of the total irrigation water payment, while the remaining 23 percent is through crop sharing. These two payment system has its own time dimension. For fixed payment, the time dimensions are: beginning of the season, throughout the season, and end season. On the average, for the five divisions, most of the villagers (60.81 percent) are paying fixed amount throughout the season. About 20.27 percent of them are paying at the beginning of the season. While only 18.92 percent of them are paying the fixed amount at the end of the season. As for the crop sharing, on the average, 26 percent are giving the payment (crops) after harvesting (Table 13).

Table 13. Payment types and time dimensions of the payment

Division name	Time dimension of fixed payment (77%)			Percent of crop share (23%)
	Beginning of the season	Throughout the season	End of the season	After harvesting
Chittagong	0.00	100.00	0.00	-
Dhaka	10.00	65.00	25.00	25.75
Khulna	33.33	44.45	22.22	22.5
Rajshahi	30.00	60.00	10.00	26.75
Rangpur	18.18	63.64	18.18	-
Total	20.27	60.81	18.92	26.00

Source: Field survey, 2013

Depth of STW

Figure 9 shows the depth of shallow tube well, in feet, used in the selected divisions of the country, comparing 2003 and 2013. All the divisions have deeper shallow tube well in 2013 compared to 2003. Also, Khulna has the deepest shallow tube compared to other divisions (Table 16). It clearly indicates the lower underground water level at present compare the past 10 years which might be the consequences of extracting excess water from underground and also might be due to the overall climate changes.

Table 14. Village-wise depth of shallow tubewell for sufficient water supply (in Feet)

Division name	Depth in 2013	Depth in 2003	Change
Chittagong	113	93	22
Dhaka	107	84	27
Khulna	146	114	28
Rajshahi	113	97	16
Rangpur	85	66	29
All	112	89	26

Source: Field survey, 2013

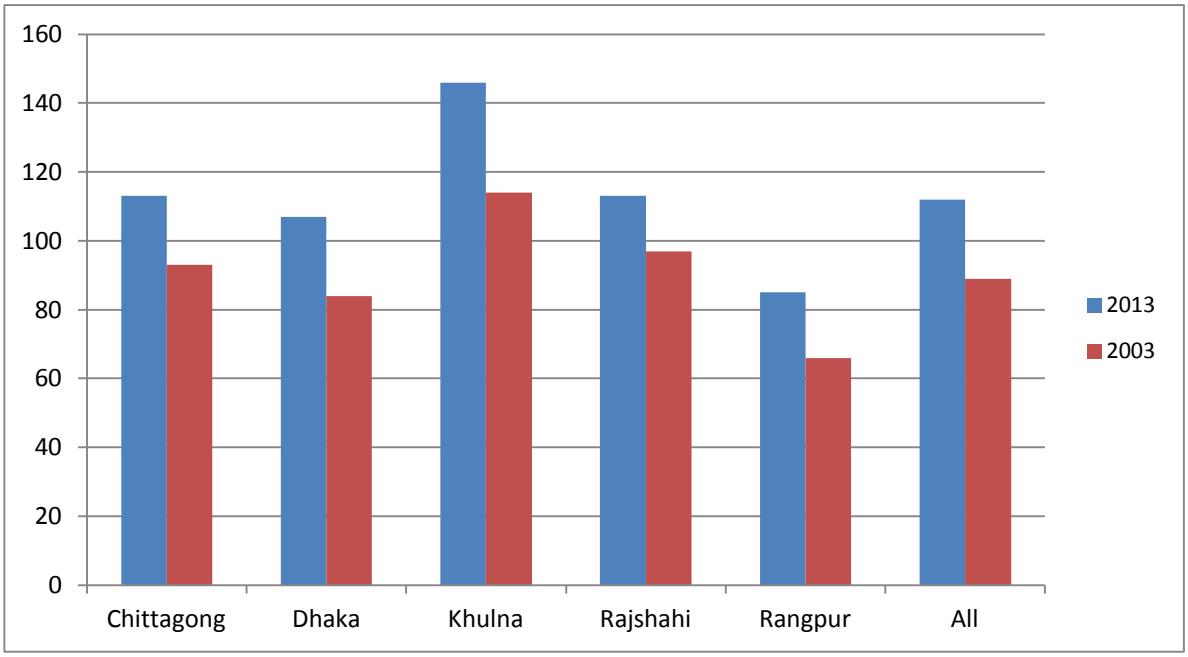


Figure 7. Depth of shallow tubewell in the selected divisions in Bangladesh in 2003 and 2013 (in feet)

Price trends

Paddy price. Figure 10 shows the trend of the paddy price from 2003 to 2014 (projected price to the farmers) for the selected divisions in Bangladesh. There has been an observed increase of price from 2003 to 2013 for all the divisions, and the price will still continue to increase in 2014, as expected by the farmers. In 2012, the paddy price was higher than in 2013 though all inputs cost were higher in 2013 than 2012. One of the reasons is government was selling rice through Open Market Sell (OMS) of last year stocked rice.

Table 15. Paddy price in different time periods (Price in BD Taka)

Division name	Paddy price in 2013	Paddy price in 2012	Paddy price in 2007/8	Paddy price in 2003	Projected paddy price in 2014
Chittagong	587.50	625.00	890.00	562.50	775.00
Dhaka	535.36	557.14	838.00	366.07	691.07
Khulna	596.00	541.00	795.00	346.00	830.00
Rajshahi	620.00	559.09	831.00	381.82	732.73
Rangpur	507.73	461.36	825.00	362.95	640.91
Total	563.23	535.10	835.80	372.97	721.56

Source: Field survey, 2013

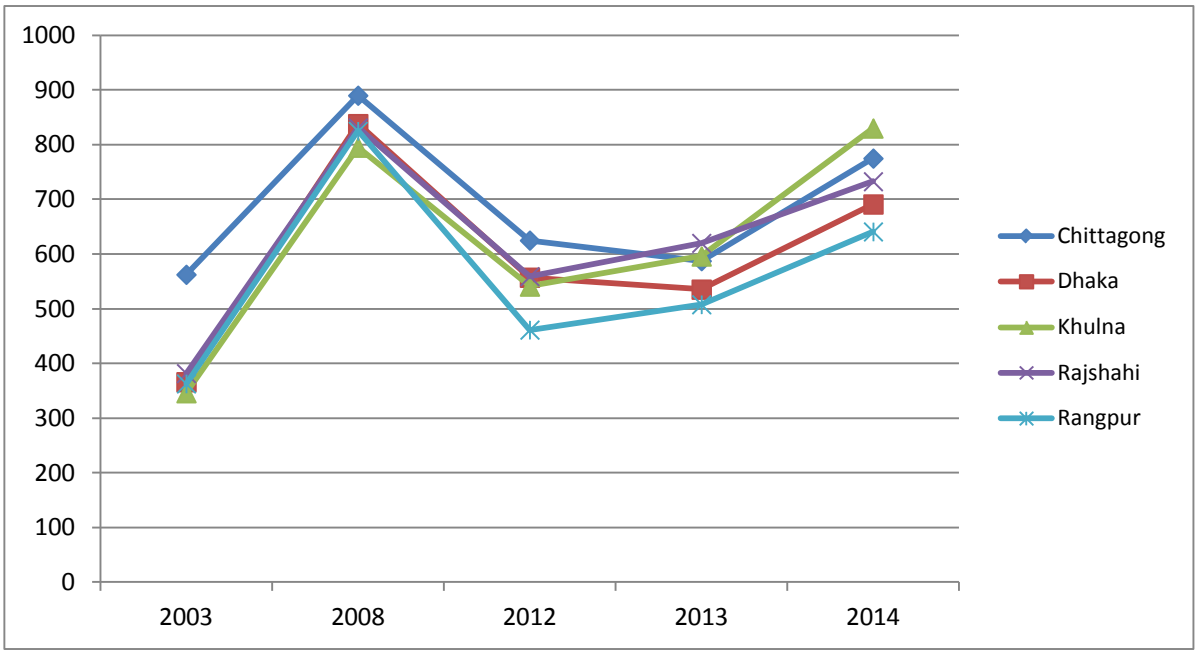


Figure 8. Patterns of Paddy prices in 2003 and 2013

Fuel (diesel) price

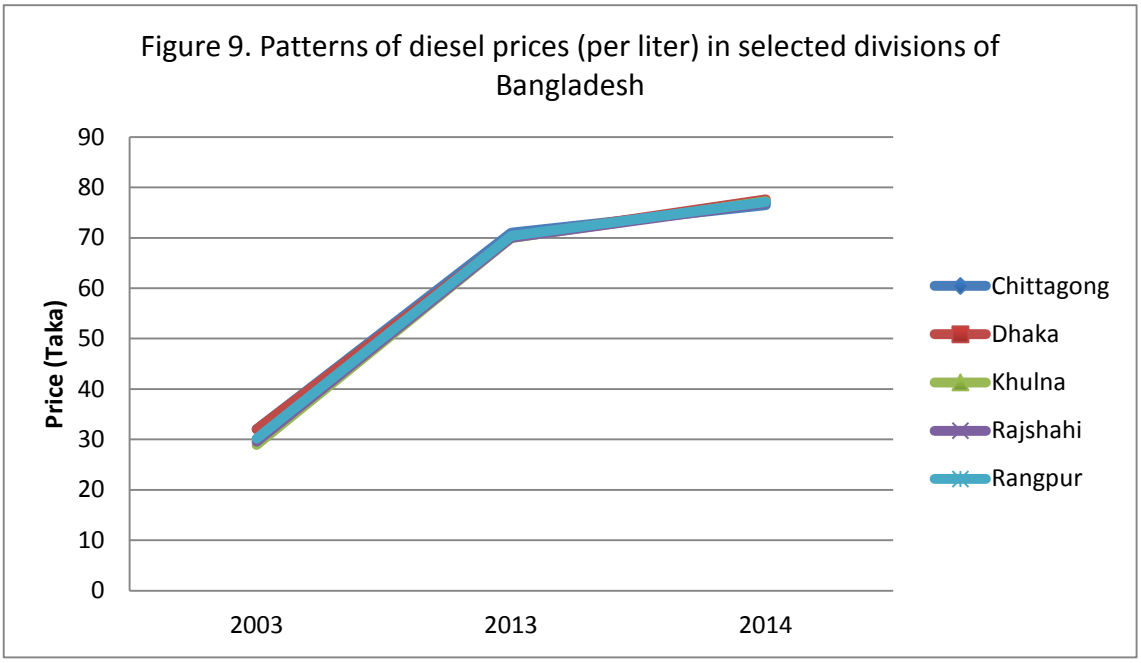
The change in diesel price from 2003 to 2013 and to 2014 as projected is shown in Figure 9. The price increasing over time and will still continues to increase in 2014 as projected by the farmers.

The price of diesel has increased more than 100% over the last 10 years. This is the same observation for all the divisions under study (Table 18).

Table 16. Fuel (diesel) price in different time periods (Price in BD Taka)

Division name	Diesel price in 2013	Diesel price in 2003	Projected diesel price in 2014
Chittagong	71.00	32.00	76.50
Dhaka	70.214	32.00	77.61
Khulna	69.95	28.90	77.25
Rajshahi	70.00	29.55	76.95
Rangpur	70.364	30.18	77.14
Total	70.18	30.38	77.23

Source: Field survey, 2013

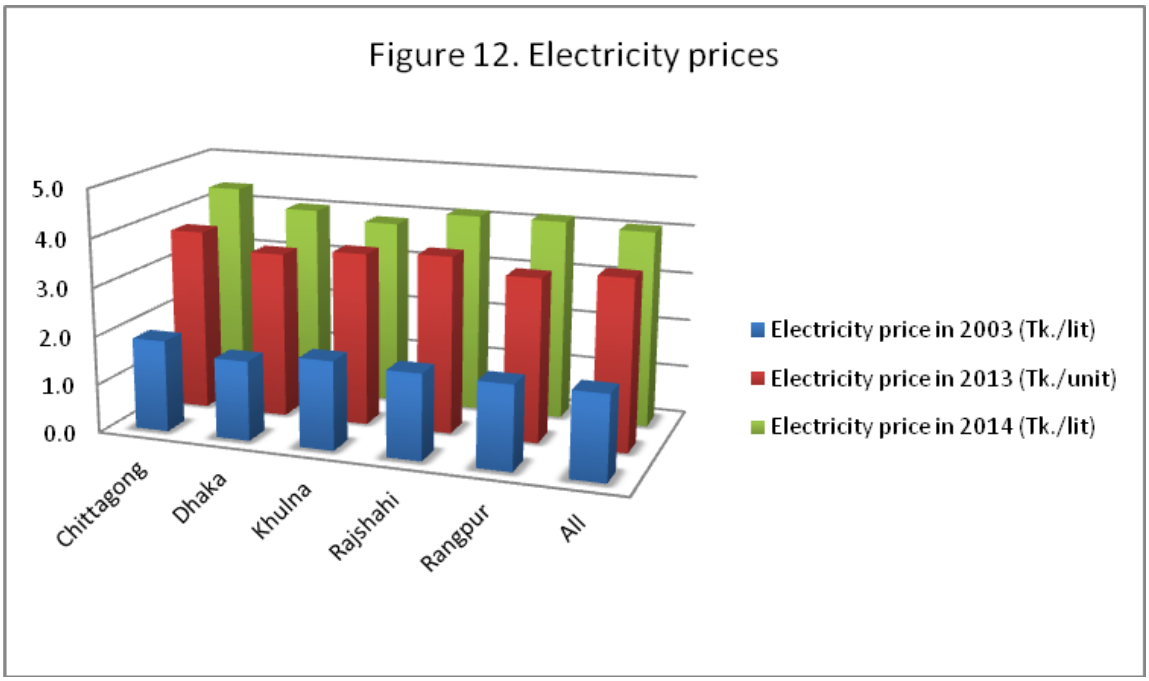


Fuel (electricity) price

Electricity prices are increasing over the years and the rate of increase is very reasonable compared to diesel price in Bangladesh. Both prices are subsidized and subsidy in electricity is much higher than subsidy in diesel price. Farmers are projected higher price of electricity in 2014 but this rate of increase is lower than the projected price of diesel in 2014.

Table 17. Fuel (electricity) price in different time periods (Price in BD Taka)

Division name	Electricity prices (Tk./unit)		
	2003	2013	2014
Chittagong	1.9	3.8	4.4
Dhaka	1.6	3.4	4.0
Khulna	1.8	3.6	3.9
Rajshahi	1.8	3.7	4.1
Rangpur	1.7	3.4	4.1
All	1.7	3.5	4.1



Occurrence of natural calamities

Table 19 shows that on the average (for the whole study area) flood occurs at least once and its duration is about 15 days, drought at least twice, prevalence of disease for at least once, only half chance of storm in a year and occurrence of rainfall for at least thrice per boro season.

Table 18. Average occurrence of natural calamities in the study area per season

Division name	No. of flood	Flood duration (days)	No. of drought	No. of storm	No. of disease attack	No of rainfall
Chittagong	0.75	12.50	0.50	0.25	0.00	4.50
Dhaka	1.57	21.68	2.51	0.75	1.75	3.61
Khulna	0.65	12.60	1.65	0.60	1.40	2.95
Rajshahi	1.23	17.36	3.68	0.18	1.32	2.36
Rangpur	1.32	7.318	1.64	0.82	1.36	2.82
Total	1.21	15.13	2.32	0.58	1.42	3.04

Source: Field survey, 2013

Quality of groundwater

Table 20 shows the different color of groundwater in the study areas. About 39.58 percent of the groundwater in the study area is clear. It was observed that the major percentage of groundwater in each division is clear. However, in Chittagong and Rangpur, the percentage of reddish groundwater is higher (100 percent for Chittagong and 40.91 percent for Rangpur). Next to clear, the groundwater tends to be cloudy (27.08%) and the reddish (26.04). Only small percent of the groundwater is either yellow or brown.

Table 19. Groundwater color in the study areas (in percent)

Division name	Clear	Cloudy	Yellow	Reddish	Brown	Total
Chittagong	0.00	0.00	0.00	100.00	0.00	100
Dhaka	42.86	21.43	14.29	21.43	0.00	100
Khulna	55.00	30.00	0.00	10.00	5.00	100
Rajshahi	50.00	31.82	0.00	18.18	0.00	100
Rangpur	18.18	31.82	4.55	40.91	4.55	100
Total	39.58	27.08	5.21	26.04	2.08	100

Source: Field survey, 2013

Awareness on quality of irrigation water

Salinity

When asked about their awareness of the salinity of the irrigation water, most of the respondents from all the divisions said they are unaware about it. This can be seen in Table 21. Majority of the respondents answered “no”. Same responses were gathered in 2003 and 2013. Farmers of Khulna division are aware more about salinity in irrigation (Table 20). The reason behind this, among the selected districts, Khulna has the most coastal areas than others.

Table 20. Awareness about the salinity of irrigation water in 2003 and 2013 (In percent)

Division name	In 2013			In 2003		
	Yes	No	Unknown	Yes	No	Unknown
Chittagong	25	75	0	25	75	0
Dhaka	0	100	0	0	96	4
Khulna	20	80	0	15	80	5
Rajshahi	0	100	0	0	91	9
Rangpur	0	100	0	0	100	0
All	5	95	0	4	92	4

Source: Field survey, 2013

Iron contamination

Table 22 shows the awareness of the villagers about the presence of iron in the irrigation water in 2003 and 2013. In 2003, most of the villagers from all the divisions were aware of the presence of iron. The same was also observed in 2013, only that the percentage of people's awareness of iron was higher in 2013.

Table 21. Awareness of the presence of iron in irrigation water (2003 and 2013)

Division name	In 2013			In 2003		
	Yes	No	Unknown	Yes	No	Unknown
Chittagong	100	0	0	100	0	0
Dhaka	64	36	0	64	32	4
Khulna	95	5	0	85	5	10
Rajshahi	77	23	0	68	23	9
Rangpur	86	14	0	82	14	4
All	80	20	0	75	19	6

Source: Field survey, 2013

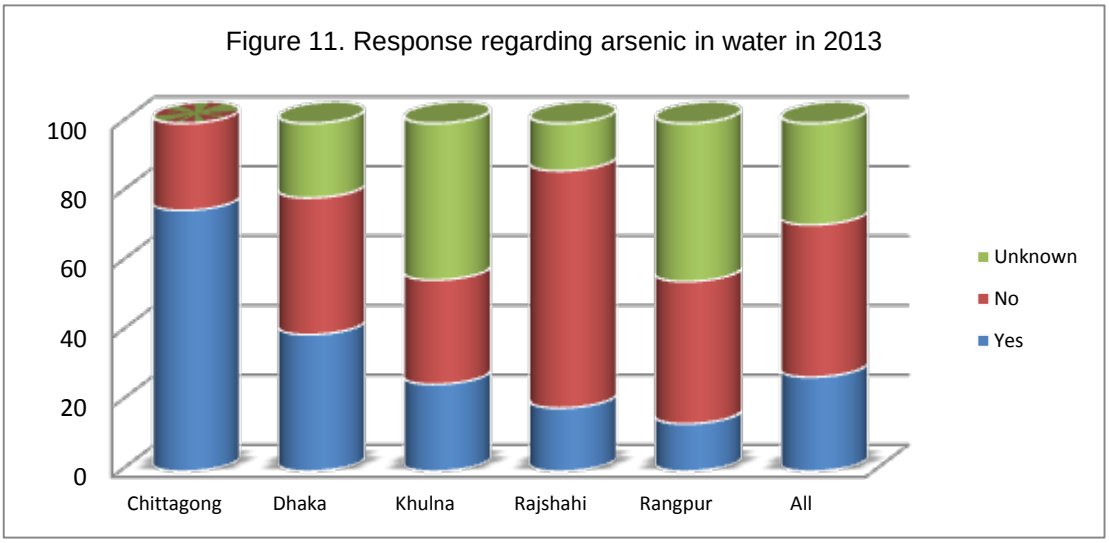
Arsenic

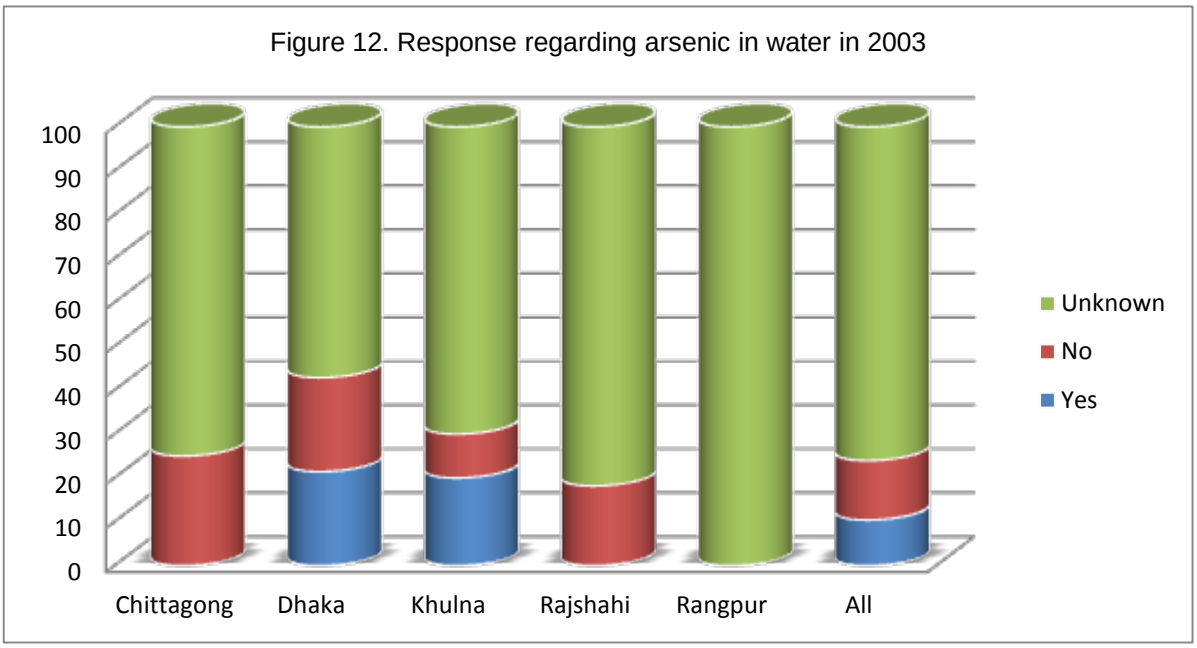
Villagers were also asked about their awareness on the presence of arsenic in their irrigation water for 2003 and 2013. In 2003, as shown in Figure 8, most of the villagers were not aware of the presence of this chemical. While 13.54 percent of them believed that there is no arsenic in the irrigation water and then the remaining 10.42 percent believed that the chemical is present in their irrigation water. In 2013, the response of the villagers has changed. About 43.75 percent of them believed that there's no arsenic in the water. Twenty nine percent were still unaware of the presence of the chemical and then 27.08 percent of then believed that there's arsenic in the water (Table 22).

Table 22. Villagers' response about arsenic in irrigation water in 2003 and 2013

Division name	In 2013			In 2003		
	Yes	No	Unknown	Yes	No	Unknown
Chittagong	75.00	25.00	0	0	25.00	75.00
Dhaka	39.29	39.29	21.42	21.43	21.43	57.14
Khulna	25.00	30.00	45.00	20.00	10.00	70.00
Rajshahi	18.18	68.18	13.64	0	18.18	81.82
Rangpur	13.64	40.91	45.45	0	0	100.00
All	27.08	43.75	29.17	10.42	13.54	76.04

Source: Field survey, 2013





Acquisitions of loan

Table 23 shows the percentage of villagers who received loansand the rent they have to pay per season for the land. On the average, 72.35 percent of the villagers receive loans. Among all the divisions, Rangpur has the highest percentage with 80.64 while Chittagong has the lowest with 28 percent. Chittagong has the lowest percentage of loan received but it has the second highest land rent among the divisions under study with 10,975 Tk./acre. Khulna has the highest land rent per season and Dhaka has the lowest rent.

Table 23. Villager-wise loan receiver and land rent per season

Division name	Loan receiver (%)	Land rent in boro season (Tk./acre)
Chittagong	28.00	10975.00
Dhaka	68.65	9332.14
Khulna	72.50	11075.00
Rajshahi	76.36	13204.55
Rangpur	80.64	10693.86
Total	72.35	10963.18

Source: Field survey, 2013

There are three identified sources of lending in the villages – bank, money lender, and NGO. In 2003, as shown in Figure 15, on the average, almost 50 percent of the villagers involved in money lending from NGOs. This is followed by private money lender and then from banks. The same was also observed in 2013 as shown in Figure 14. Most of the villagers were involved in NGOs then to money lenders and least to banks (Table 25). By the years, loan received from NGOs by the villagers have increased from 48% in 2003 to about 65% in 2013.

Table 24. Involvement of Villagers in the different borrowing sources in 2003 and 2013 (In percent)

Division name	Villagers involvement in 2013			Villagers involvement in 2003		
	Bank	Money lender	NGO	Bank	Money lender	NGO
Chittagong	7.50	9.25	83.25	13.75	17.50	68.75
Dhaka	15.79	28.21	56.00	22.96	36.07	40.96
Khulna	14.65	11.60	73.75	24.90	27.50	47.60
Rajshahi	13.09	20.14	66.77	19.23	28.09	52.68
Rangpur	13.73	23.18	63.09	17.05	34.32	48.64
All	14.11	20.96	64.93	20.77	31.28	47.95

Source: Field survey, 2013

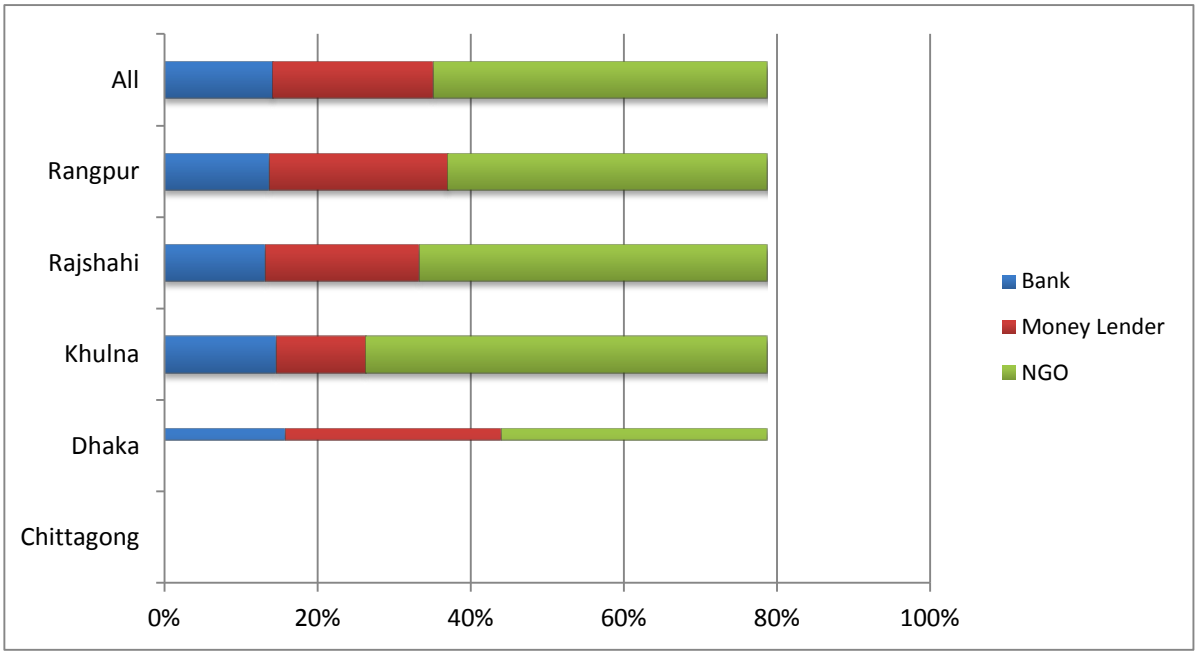


Figure 13. Loan sources of the villagers in 2013

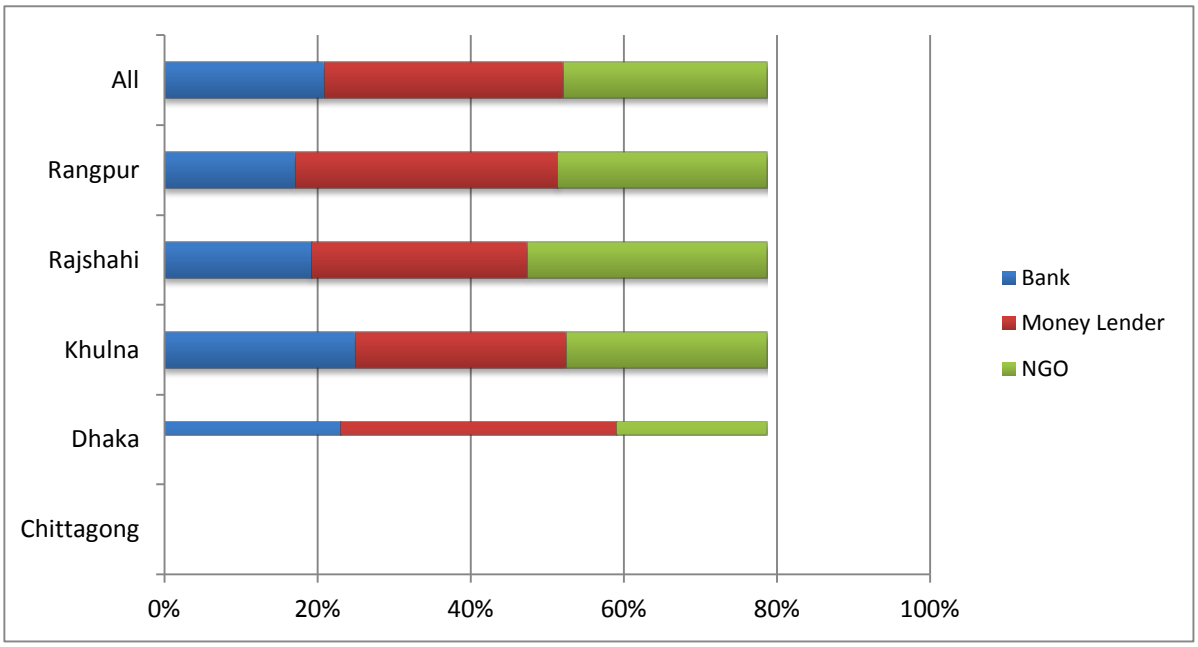


Figure 14. Loan sources of the villagers in 2003

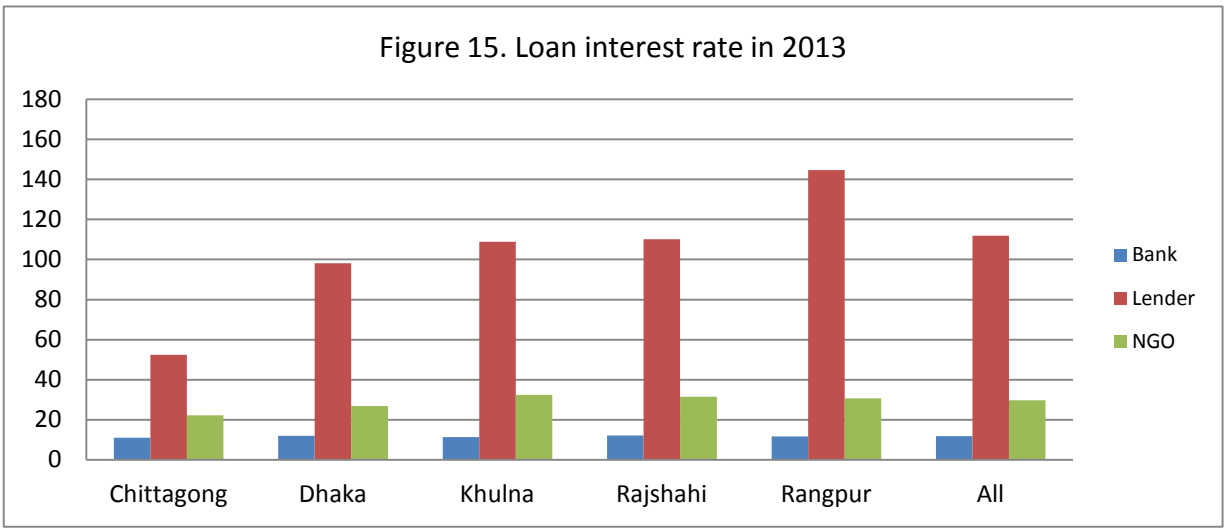
As for the loan interest rates, Figure 16 and Figure 17 show how the rate differs from each division and by the source of loan money. Figure 17 shows that in 2003, the interest rate from the money lender was the highest. This is then followed by interest rate in NGOs and then the

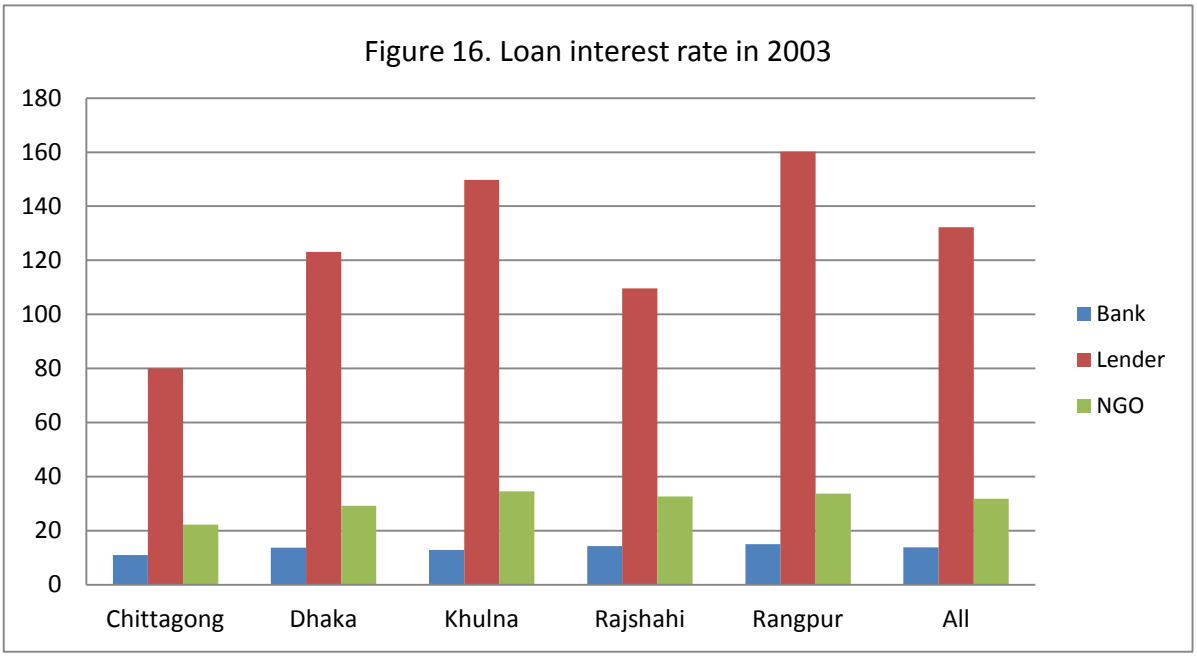
smallest is from banks. This was the same for all the divisions that year. In 2013, the average interest rate among the study areas has decreased in comparison to 2003. Figure 16 then shows the comparison of the interest rates from different sources for the 5 divisions under the study in 2013. Although the rate has decreased, on the average, the same trend can still be observed. Interest rate is highest from money lender, followed by NGO and then by bank (Table 26).

Table 25. Villagers' loan interest rate from different sources in 2003 and 2013 (In percent)

Division name	In 2013			In 2003		
	Interest rate at bank	Interest rate at lender	Interest rate at NGO	Interest rate at bank	Interest rate at lender	Interest rate at NGO
Chittagong	11.00	52.50	22.25	11.00	80.00	22.25
Dhaka	12.04	98.11	26.93	13.75	123.18	29.25
Khulna	11.45	108.90	32.45	12.85	149.75	34.55
Rajshahi	12.11	110.14	31.45	14.32	109.64	32.64
Rangpur	11.77	144.55	30.64	15.00	160.18	33.73
All	11.83	111.85	29.77	13.86	132.29	31.86

Source: Field survey, 2013





Likelihood percent of refusing irrigation water

Command area per tubewell is reducing over the years and percent of rice land per tubewell is also decreasing which we have mentioned here the tubewell owner density. The amount of water and numbers of irrigation per season requested by the farmers are not given always to the users. We have calculated the percent of refusing irrigation water per season dividing number of denied

by the number of irrigation requested and we have multiplied it by 100. This is named as likelihood percent of refusing irrigation water. The higher number of it means the higher degree of refusing irrigation water to the user's plot. The command area is the highest in Dhaka division and the meaning of it is the probability of using machine capacity is higher for the tubewell owner in Dhaka division compared to others tubewell owners. On the other hand the percent of rice land per tubewell is higher in Chittagong division and the likelihood percent of refusing irrigation water is higher in Chittagong division as well. Higher percent of users' land in a tubewell may increase the higher percent of refusing irrigation water.

Table 26. Command area, owner density and likelihood percent of refusing irrigation

Division name	Command area (ha)	Tubewell owner density	Likelihood percent of refusing irrigation
Chittagong	3.0	8.9	9.0
Dhaka	3.3	4.6	5.1
Khulna	1.4	1.8	4.7
Rajshahi	1.9	3.6	6.3
Rangpur	2.1	3.1	5.7
All	2.3	3.6	5.6

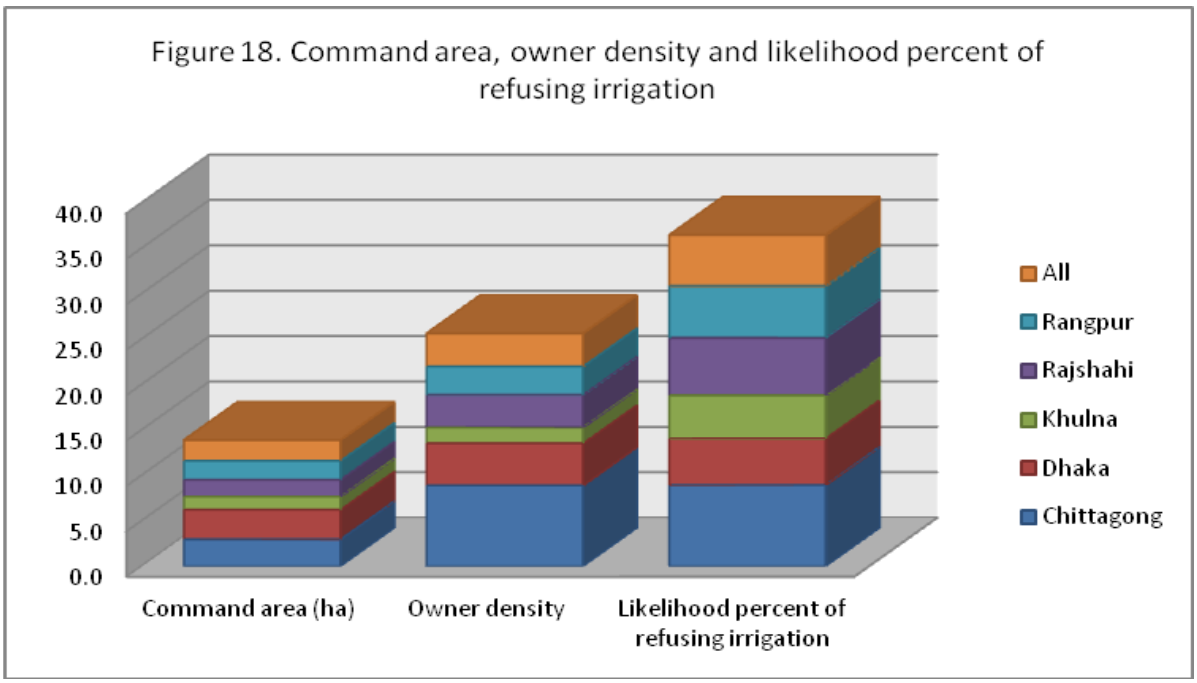
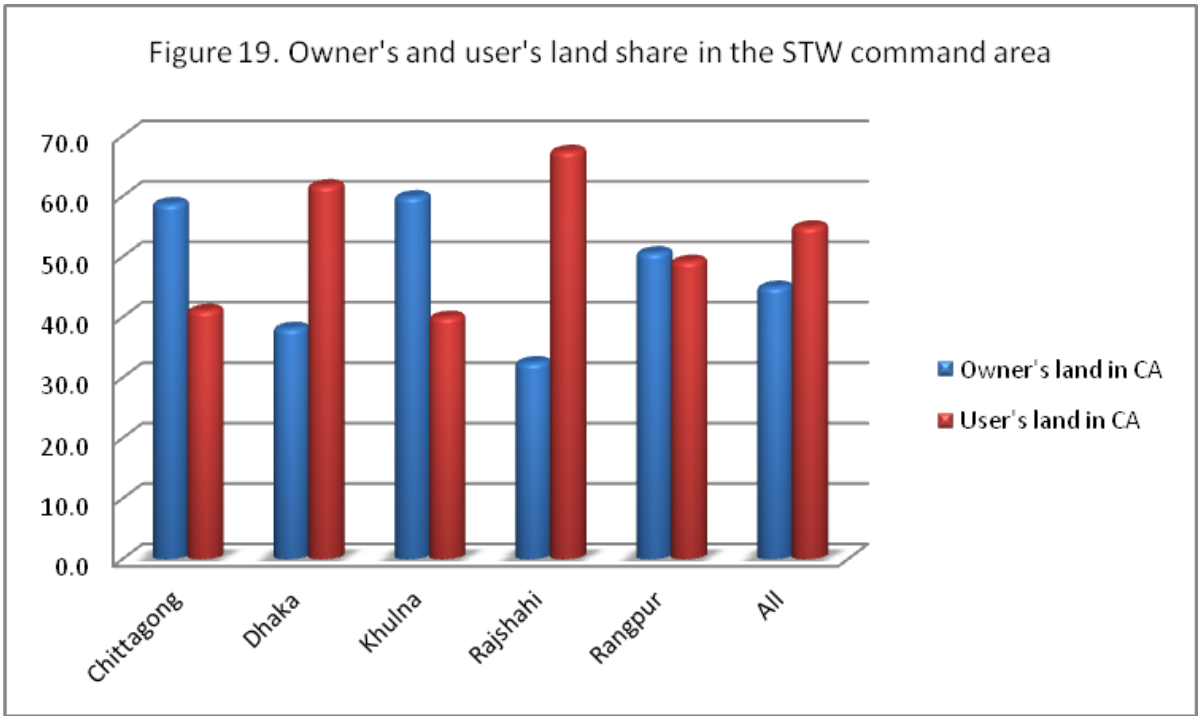


Table 27. Tubewell owner and user's land in a command area of STW

Division name	Owner's land in command area (%)	User's land in command area (%)
Chittagong	58.8	41.2
Dhaka	38.2	61.8
Khulna	60.0	40.0
Rajshahi	32.5	67.5
Rangpur	50.7	49.3
All	45.0	55.0

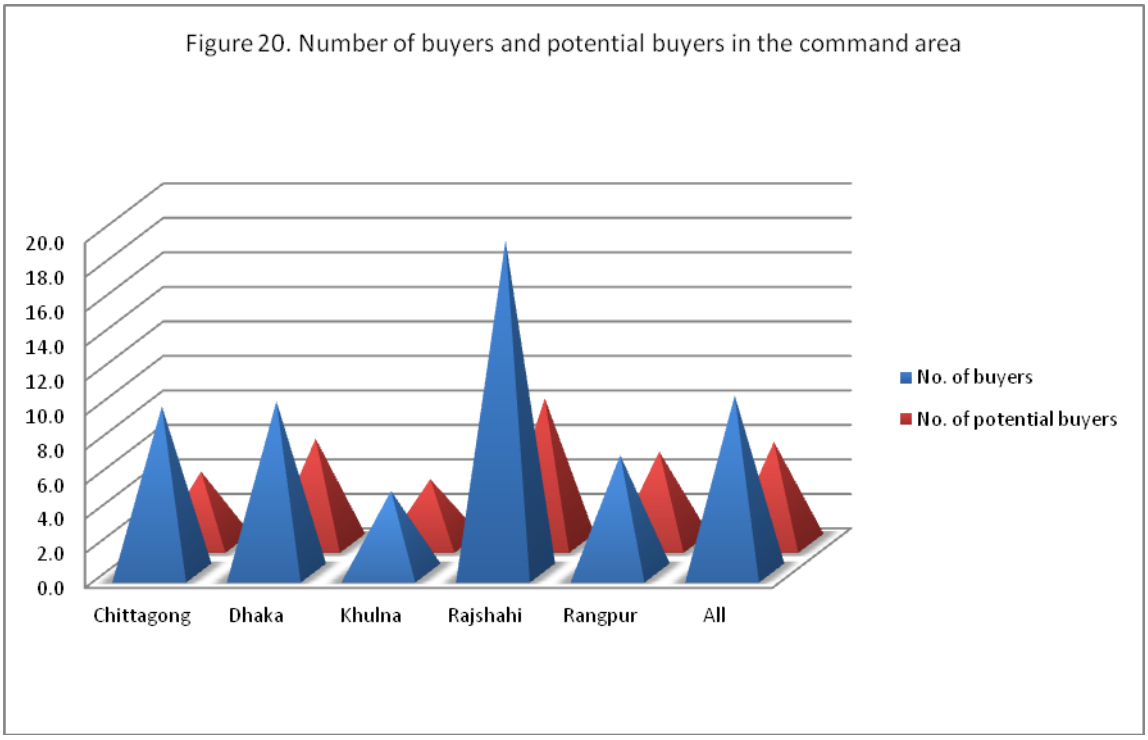
It is revealed that user's land percent is on an average higher in a command area. In the early stage of irrigation, the user's land share was more since the number of tubewell was less. That time the engine capacity was higher.



The average number of buyers are 10 in a tubewell. There is a possibility to increase this number if the tubewell owner can continue the goodwill or his reputaion more in future. He may try to increase the present situation so that other potential buyer may come to take water from his tubewell though it depends on the location of the buyer's plot.

Table 28. Number of buyers and potential buyers in a tubewell in the different divisions

Division name	No. of buyers	No. of potential buyers
Chittagong	9.7	4.2
Dhaka	10.0	6.1
Khulna	4.8	3.7
Rajshahi	19.3	8.4
Rangpur	6.8	5.3
All	10.3	5.9



Disputes in irrigation

Table 30 shows the percentage of disputes resolved by different sections of the villages in the study areas. About 50 percent of the disputes in the village of the different divisions were solved by the buyers and sellers through private talk. Group of village elders or the village council, on the average, was able to resolve 40% of the disputes. Only small percentage of the disputes are resolved by the court system (3.36 percent), a single trusted individual (2.68 percent) a member of the buyer or seller's family (2.01%), and less than 1 percent by other means. In Chittagong, disputes were resolved by either the village council or member or the buyer's or seller's family.

Table 29. Dispute resolved by different section of the villagers in the study areas (in percent)

Division name	Group of village elders/village council	Buyer and seller resolve privately	A single trusted individual	A member of the buyer or seller's family	The court system	Others	Total
Chittagong	50.00 (2)	0	0	50.00 (2)	0	0	100 (4)
Dhaka	39.53 (17)	48.84 (21)	2.33 (1)	0	6.98 (3)	2.33 (1)	100 (43)
Khulna	41.67 (15)	52.78 (19)	2.78 (2)	0	2.78 (1)	0	100 (36)
Rajshahi	26.67 (8)	63.33 (19)	6.67 (2)	3.33 (1)	0.00	0	100 (30)
Rangpur	52.78 (19)	44.44 (16)	0	0	2.78 (1)	0	100 (36)
All	40.94 (61)	50.34 (75)	2.68 (4)	2.01 (3)	3.36 (5)	0.67 (1)	100 (149)

Source: Field survey, 2013 Figures in the parentheses are number of disputes

Another way of resolving disputes in the villages is through monetary fine. Among the different sections of the villagers, the group of village elders or the village council, on the average, was able to resolve more disputes, 36.59 percent, through monetary fine. Around one thirds (34.15 percent) of the disputes were resolved through other sections of the villagers those did not have any specific section in a society. In Chittagong, it was observed that all disputes were resolved through a member of the buyer's or seller's family.

Table 30. Dispute resolved by different sections of the villagers through monetary fine in the study areas

Division name	Group of village elders/village council	Buyer and seller resolve privately	A single trusted individual	A member of the buyer or seller's family	The court system	Others	Total
Chittagong	0	0	0	100 (2)	0	0	100 (2)
Dhaka	33.33 (4)	16.67 (2)	0	0	16.67 (2)	33.33 (4)	100 (12)
Khulna	42.86 (6)	21.43 (3)	7.14 (1)	0	7.14 (1)	21.43 (3)	100 (14)
Rajshahi	28.57 (2)	14.29 (1)	0	0	0	57.14 (4)	100 (7)
Rangpur	50.00 (3)	0	0	0	0	50.00 (3)	100 (6)
Average	36.59 (15)	14.63 (6)	2.44 (1)	4.88 (2)	7.32 (3)	34.15 (14)	100 (41)

Source: Field survey, 2013 Figures in the parentheses are number of disputes

Table 30 and Figure 18 show that in Dhaka division farmers solve problems regarding irrigation at village level where they sit together and come for amicable solution but in Khulna, sellers and buyers are the main actors to solve their problem. In every division, some people always help to solve the problem but they are not actually leaders. Some cases they are relative, neighbor, friend, etc.

Table 31. Dispute resolve by different section of the villagers through land ownership change in the study areas

Division name	Group of village elders/village council	Buyer and seller resolve privately	Others	Total
Chittagong	0	0	0	0
Dhaka	33.33 (2)	50.00 (3)	16.67 (1)	100 (6)
Khulna	0	72.73 (8)	27.27 (3)	100 (11)
Rajshahi	14.29 (1)	28.57 (2)	57.14 (4)	100 (7)
Rangpur	11.11 (1)	66.67 (6)	22.22 (2)	100 (9)
All	12.12 (4)	57.58 (19)	30.30 (10)	100 (33)

Source: Field survey, 2013 Figures in the parentheses are number of disputes solved through land ownership change

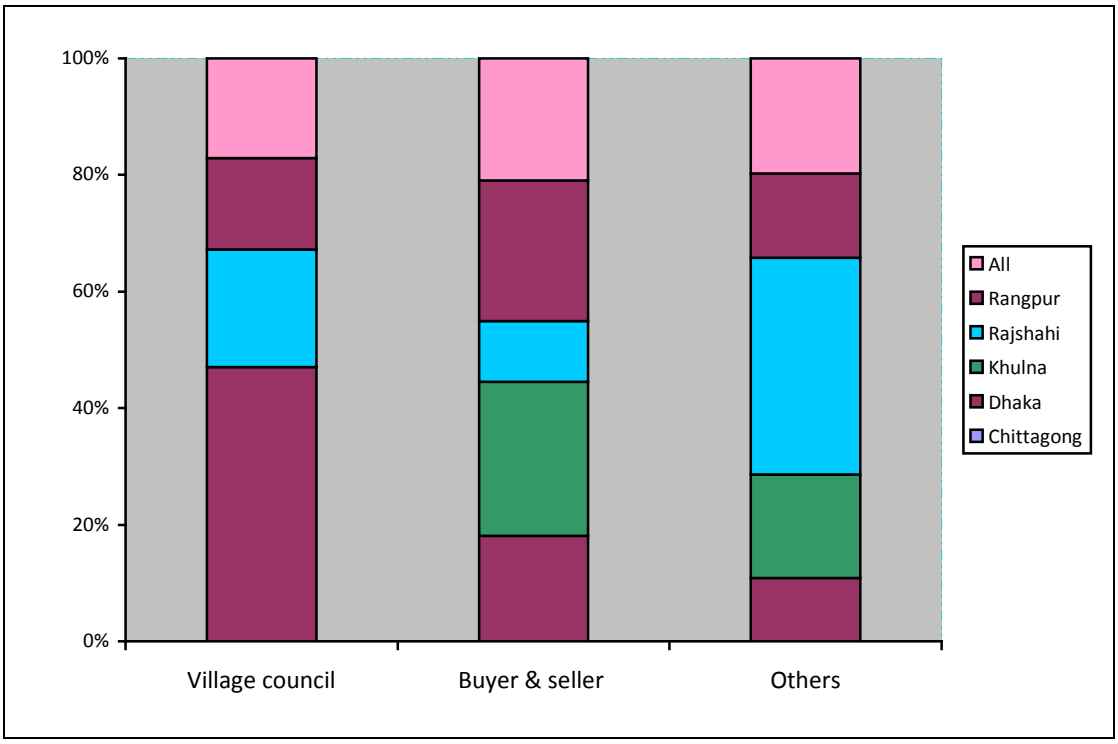


Figure 20. Dispute solution by changing ownership of land

Disputes can also be solved by the different sections of the villagers through ostracism. In Chittagong, there was no record for disputes resolved through this means. And on the average, for all the divisions, most of the disputes through ostracism were resolved by the group of village elders or village council. Only small percentage of disputes is resolved by other sections in the village.

Table 32. Dispute resolved by different section of the villagers through Ostracism in the study areas

Division name	Group of Village Elders/Village Council	Buyer and Seller Resolve Privately	A Single Trusted Individual	The Court System	Others	Total
Chittagong	0	0	0	0	0	0
Dhaka	72.73 (8)	9.09 (1)	0	9.09 (1)	9.09 (1)	100 (11)
Khulna	72.73 (8)	0	0	0	27.27 (3)	100 (11)
Rajshahi	25.00 (3)	33.33 (4)	8.33 (1)	0	33.34 (4)	100 (12)
Rangpur	73.34 (11)	13.33 (2)	0	0	13.33 (2)	100 (15)
Average	61.22 (30)	14.29 (7)	2.04 (1)	2.04 (1)	20.41 (10)	100 (49)

Source: Field survey, 2013 Figures in the parentheses are number of disputes solved through Ostracism

Another way of resolving disputes is through free irrigation since s/he failed last season to supply water and this free irrigation is a way of punishment to the seller. Chittagong is another unique case, wherein no recorded disputes were resolved through free irrigation. Considering all the divisions, on the average, 76.92 percent of the disputes that were resolved through free irrigation were not resolved by any sections that were identified in the survey. Resolution through buyers and sellers accounted for about 15.38 percent while 7.69 percent were through the member of the buyer's or seller's family (Table 33).

Table 33. Dispute resolved by different section of the villagers through free irrigation in the study areas (In percent)

Division name	Buyer and seller resolve privately	A member of the buyer or seller's family	Others	Total
Chittagong	0	0	0	0
Dhaka	50.00 (1)	0	50.00 (1)	100 (2)
Khulna	0	0	100.00 (3)	100 (3)
Rajshahi	20.00 (1)	0	80.00 (4)	100 (5)
Rangpur	0	33.33 (1)	67.67 (2)	100 (3)
All	15.38 (2)	7.69 (1)	76.92 (10)	100 (13)

Source: Field survey, 2013 Figures in the parentheses are number of disputes solved through free irrigation

Summary and conclusions:

Irrigation started in Bangladesh since 1950s. Groundwater irrigation through STW and DTW started after 1970s. Farmers reported that they are using groundwater since 1981. Information from 96 villages show the improvement of infrastructures at village level like road conditions, market, school, health center, etc. Education and health care facilities are increasing day-by-day. Due to have the better access and improvement of market facilities, farmers have more opportunity to sell their products though they have some complains of low prices. It is already common that farmers shift from agriculture to other occupation, which has good return at village level. Wage labor service is reducing significantly and there had been an improvement in mobility of women, where they have opportunity to perform other activities. Land topography of the villages represents the overall land type in Bangladesh. Most of the land is characterized as medium type land with different soil types, which is mostly black soil. Arable land increases over the years. Irrigated land, especially rice land, has increased remarkably in Khulna and Rangpur divisions. Villagers often use groundwater for irrigation purposes. There are plenty sources of clear water in the villages, however it has been observed that quality of water worsens over the period of time – from clear to cloudy and reddish color. STW and DTW are the main means of groundwater irrigation. Due to tremendous increase in numbers of STW, DTW

command area decreases and command area under STW decreases with the significant increase in the number of users/adopters of the machine. It implies the suitability of STW as farmers' friendly irrigation technology. There are some changes in the ratio of owner and buyers land in STW command area. Owners' land increases and buyers' land decreases, which indicate that more farmers have more opportunity to own STW.

There are three types of payment systems at the village level. Irrigator farmers are shifting from crop share to fixed rate and two part tariff systems since it is economically viable for the buyers. Paddy prices are fluctuating every year, which is not favorable for the sustainable food grain production. Input prices like seed, diesel, fertilizer, insecticides, etc. are increasing over the years. Due to increasing demand for groundwater every year, the depth of groundwater level is going down. Using more water from underground, problems on iron, arsenic and saline contamination are becoming a big issue in some areas.

To perform agricultural activities, farmers need credit facilities. More than seventy percent farmers are taking credit from bank, money lenders and NGOs. Previously, farmers were taking credit from money lenders, but due to higher interest rates implemented by money lenders, farmers are getting more credit from NGOs. Interest rate from bank and NGOs' are becoming lower, but farmers take credit from NGOs due to easier access that from Bank. Interest rate of credit from NGOs' is higher in Khulna division. In selling irrigation water, there arise some disputes due to have insufficient and irregular supply of water. It is good that very few of them come to legal court system for solution. Most of the disputes resolve in the village level - village council or people of the particular area resolve the problem. Some cases, they do the changes of the ownership of the plot, free irrigation, monetary fine, ostracism, etc. Most of the cases of seller and buyer resolve their own problems through discussion at the respective village.

Policy recommendations:

Area coverage and suitable equipments increase due to the policy adoption of importing small machine for groundwater irrigation through market liberalization in late 1980s. Now time to ensure the efficient utilization of the machine's capacity and also needs to be careful about the efficient use of groundwater since depth of groundwater is going down. To accomplish that

government needs to have policy for reasonable stable prices for the agricultural outputs particularly the price of boro rice. Otherwise, farmers may go for producing other crops which maybe an intimidation for the food sufficiency in Bangladesh. Division wise irrigation technology and efficient payment method and guidelines for price fixation of irrigation may help to reduce the use of groundwater which will somehow give assurance for the long time use of it. In addition to that, since farmers have more interest for AWD technology, the government can make it available to the farmers through DAE system. It may take time to adopt this technology by the irrigator farmers but its ultimate use will reduce the cost of irrigation which is beneficial for the farmers.

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