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Environmental Impact of Teesta Barrage on the Command Area in Bangladesh

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M.Phil. Thesis

By

Sunil Chandra Roy
Session: 2007-2008

Submitted to the Institute of Environmental Science
University of Rajshahi
Rajshahi-6205, Bangladesh

June, 2014

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A Thesis

Submitted to the Institute of Environmental Science (IES) University of Rajshahi for the Degree
of
Master of Philosophy (M. Phil)
In
Environmental Science

By

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Session: 2007-2008
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Dedicated

To

My Beloved

Parents

DECLARATION

I do hereby declare that the M. Phil. thesis entitled **"Environmental Impact of Teesta Barrage on the Command Area in Bangladesh"** submitted to the Institute of Environmental Science, University of Rajshahi, Bangladesh is an independent work carried out by me in the Computer Lab, Institute of Environmental Science, University of Rajshahi under the Principal supervision of Dr. Md. Ahul Kalam Azad, Associate Professor, Institute of Environmental Science, University of Rajshahi, and Co-supervision of Dr. Md. Lutfor Rahman Professor, Department of Mathematics University of Rajshahi. The thesis had not been submitted previously for any degree and award.

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CERTIFICATE

We do hereby certify that the thesis entitled "Environmental Impact of Teesta Barrage on the Command Area in Bangladesh"is an original research work conducted by Sunil Chandra Roy in partial fulfillment of the requirements for the degree of **Master of Philosophy** (M.Phil) in Environmental Science. To the best of our knowledge, this research work is researcher's own achievement, not a duplication of any previous work. Through this research work Mr. Sunil Chandra has certainly made a distinct contribution to the arena of Environmental change due to Teesta Barrage and its impact on agriculture groundwater rainfall in the greater district of Rangpur division context of Bangladesh. This thesis or its any part has not been submitted to any other university for higher degree.

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Sunil Chandra Roy

ABSTRACT

Bangladesh Water Development Board (BWDB) has implemented Teesta Barrage Irrigation Project in 1994. The objectives of this mega project were flood control and creation of supplementary irrigation facilities for an area of 1,54,250 ha under the greater Rangpur district. This study was conducted to identify the environmental impact of Teesta Barrage Irrigation Project on agriculture, groundwater and rainfall in the project area by trend analysis of two periods: before and after project. For trend analysis 22 years (1983-2004) ground water table and 20 years (1984-2003) rainfall data were used.

From ground water data analysis, it is found that seasonal mean ground water table was up in post-project period (1994-2005) of Teesta Barrage Irrigation Project and level was down in pre-project period (1982-1993). The mean differences of ground water table of these two periods was significantly different (0.01% level) in all six seasons of summer, rainy, autumn, late autumn, winter, spring and summer. Therefore, it is concluded that Teesta Barrage Irrigation Project has positive impact on ground water resources and improved the ground water table in the command area.

From rainfall data analysis, it is observed that mean rainfall in post-project period (1994-2003) of Teesta Barrage Irrigation Project was increased in

all six seasons in the study area compare to mean rainfall of pre-project period (1984-1993). However, the mean difference rainfall between the periods (1984-1993) & (1984-2003) was found significant only in winter season. Therefore, it is concluded that Teesta Barrage Irrigation Project has positive impacts on rainfall pattern in the project area.

As per respondents' opinion, Teesta Barrage Irrigation Project has also positive impacts on the following environmental components.

i) Increased food production for HYV-Boro and T-aman cultivation
ii) Increased fruiting plants and social forest plantation
iii) Increased drinking water availability
iv) Decreased water born diseases
v) Improved income and standard of life of local people

However, Teesta Barrage Irrigation Project has reduced the open fisheries in the project area. Jute and aus cultivation are dramatically reduced in this area.

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ABBREVIATIONS

ADB	Asian Development Bank
BBS	Bangladesh Bureau of Statistics
BDHS	Bangladesh Demographic
BRDB	Bangladesh Rural Development Board
BWDB	Bangladesh Water Development Board
BWFMS	Bangladesh Water and Flood Management Strategy
CAD	Command Area Development
CE	Chief Engineer
CHR	Canal Head Regulator
DC	District Commissioner
DG	Director General
FCD	Flood control and Drainage
FDR	Flood Damage Rehabilitation
FGD	Focus Group Discussions
FSL	Full Supply level
FY	Financial Year
GO	Government Organization
GOB	Government of Bangladesh
Ha	Hectare
HYV	High Yielding Variety
IDB	Islamic Development Bank
IMED	Implementation Monitoring and Evaluation Division
IPM	Integrated Post Management
IWRM	Integrated Water resources Management
KM	Kilometer
MDG	Millennium Development Goal

MEU	Monitoring & Evaluation Unit
MOWR	Ministry of Water Resources
MP	Murate of Potash
MT	Metric Ton
NCA	Net Cultivable Area
NGO	Non-Government Organization
O& M	Operation & Maintenance
PCR	Project Completion Report
PDS	Project Data Sheet
PP	Primary Performa
PSU	Primary Sampling Unit
QCO	Quality Control Officer
READ	Research Evaluation Associates for Development LTD.
RFP	Request for Proposal
SDE	Sub-Division Engineer
SRS	Systematic Random Sampling
T.Aman	Transplanted Aman
TBP	Teesta Barrage Project
TK	Taka
TOR	Terms of Reference
TSP	Triple Super Phosphate
WDB	Water Development Board
WMA	Water Management Association
WMC	Water Management Committee
WMF	Water Management Federation
WMG	Water Management Group
WUG	Water Users Groups

Chapter 1
Introduction

1.1 General

Food production is always a crying need and it directly depends on irrigation system, irrigated lands and other associated factors. However, surface water is the best option to produce more food which would enable the farmers to use cheaper irrigation water that would also be environment-friendly. Moreover, water is becoming an increasingly scarce commodity because most region of Bangladesh is located in semi-arid regions with a high population growth. Groundwater has played an important role for irrigating agricultural lands of Bangladesh. Supply of irrigation water for crops is a matter of life and death of farmers. However, water augments productivity in the agricultural sector and the cost- effectiveness of irrigation infrastructure are augmentative necessary to enhance the reliability of the water supply to the farmers. In fact, difficulties of having access to water frequently determine the position of the poor on the poverty scale (ADB, 2005, Islam and Akram, 2007).

Northern Bangladesh is a plain land area and 90% of its population relies on agricultural production, depending on nature. Due to lack of water they cannot cultivate the land in the dry season. Every year they used to face drought and lose a huge amount of crop. The crop damage from drought is many times higher than the damage from flood (MPO, 1987). But the Teesta Barrage Irrigation Project (TBIP) is a blessing to the distressed people with supplying irrigation water through a network of canal system and a Barrage across the river Teesta and Doani in Lalmonirhat District mainly for supplementary irrigation during monsoon. It also caters to the requirements as possible during lean period by crop diversification and irrigation rotation. Moreover, it is also likely to create better job opportunities, leading to economic emancipation of the poverty stricken people. In the next 25 years, food demand of the country is expected to increase by 29% (NWMP, 2000) This will require cropping intensity to be increased with round the year irrigation.

India constructed a Barrage at Gazoldoba over the Teesta River which is around 100 km upstream of Teesta Barrage of Bangladesh. In the rainy season they depart excessive water through the Gazoldoba Barrage to the Bangladesh area causing floods. But in the dry season India retraces water from the Teesta River for using in agricultural fields and navigation purposes in their land. So lacking in sufficient flow of water in the Teesta River irrigation system is likely to be hampered and climatic conditions of the surrounding region has been dampened day by day. "We construct reservoirs to store water and we abstract water from streams and apply it to the irrigation of land without any regard to the apparent intention of nature.

We protect the banks of rivers from natural erosion and we dredge up sand and mud from places in which nature intended it to remain. There are, of course, limits within which we must confine our efforts, and success depends on a due apprehension of these limits, and on a just sense of proportion." – W.A. Inglis (1909)

The agricultural development projects have to ensure a better living for the local people, but most often environmental issuing are generated by the projects in practice, Variation environmental parameters e. g rainfall, ground water table, etc. During the year has led to the division of the year into distinct crop seasons. Therefore, the main objective of the TBP is to augments agricultural production through irrigation and thereby create employment opportunities in the vast area of northern Bangladesh by supplying sufficient water during monsoon season when there might have irrigation water scarcity.

1.2 Feasibility Report

The preliminary feasibility report of the project was prepared in 1960 by m/s. Haigh Zinn and Associates in collaboration with A.C.E. Ltd. (Pakistan) and the second one was prepared by m/s Binnie and Partners Ltd. during 1968-70.

Under the changed circumstances Engineers of Bangladesh Water Development Board (BWDB) and BUET reviewed the previous report and conducted fresh survey, investigation, furnished Planning and Detailed Engineering Design.

1.3 Project Profiles

The short profile of the project under evaluation is given below.

- ♦ Name of the project : Teesta Barrage (1st Phase) project
- ♦ Administrative Ministry : Ministry of Water Resources
- ♦ Executing Agency : Bangladesh Water Development Board (BWDB)
- ♦ Location of the project : Rangpur, Nilphamari and Dinajpur Districts
- ♦ Date of commencement : 1960-1961 and actual physical work started in 1979- 1980.
- ♦ Date of Completion : 1996-1997 as per PP and as per PCR: 1997-1998
- ♦ Project cost (In lakh) : The total cost: Tk 98503.10 lake. (Tk local 94042.6 And FE Tk. 2832,4+27.000mt wheat)

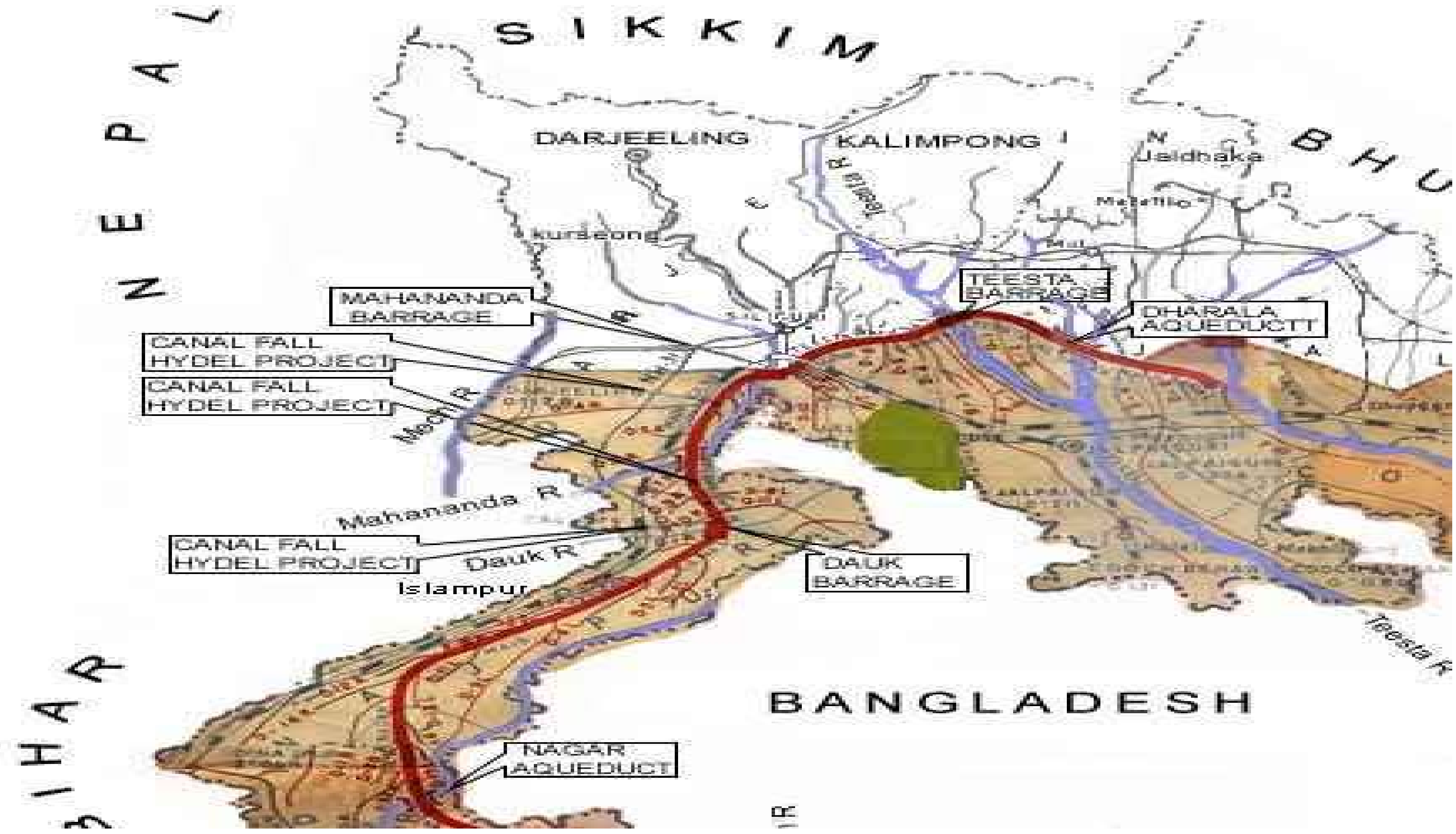

Figure 1.1 Map of Teesta Barrage Project

Figure 1.2 Photograph of Teesta Barrage

1.4 Objective of the Project

The Teesta Barrage project is an irrigation flood control and drainage project. The objective was to increase agricultural production by gravity with flood protection and drainage facilities to a gross area of 1, 54,250 ha, of which net benefited area is 1, 11,406 ha.

1.5 Components of the project (Phase-I)

The gross area of Teesta Barrage project (TBP) is 750,000 ha (=7,500 km^2), of which 540,000 ha are devoted for irrigation areas. To derive the early benefits, the TBP has been phased out vise Phase-I and Phase-II.

Phase I: Demarcated by Parbatipur-Kaunia Railway line on the South of Nilphamari covering a gross area of 154,250 ha of which net irrigable area is 111, 406 ha.

Table 1.1 The major physical components comprise the follwing (Rel.PP)

Sl.	The major physical components as per PP	Target (quantity)
1	Barrage	1 (length 615 m). 44 vent
2	Canal Head Regulator (CHR)	1 (length 110.36 m). 8 vent
3	Irrigation Canal	646.67 km
4	Drainage Canal	380 km
5	Embankment	80 km
6	Irrigation Structures	1110 no.
7	Drainage Structures	120 no.
8	Slit Trap	1 no.
9	Field Turnout	2000 no.

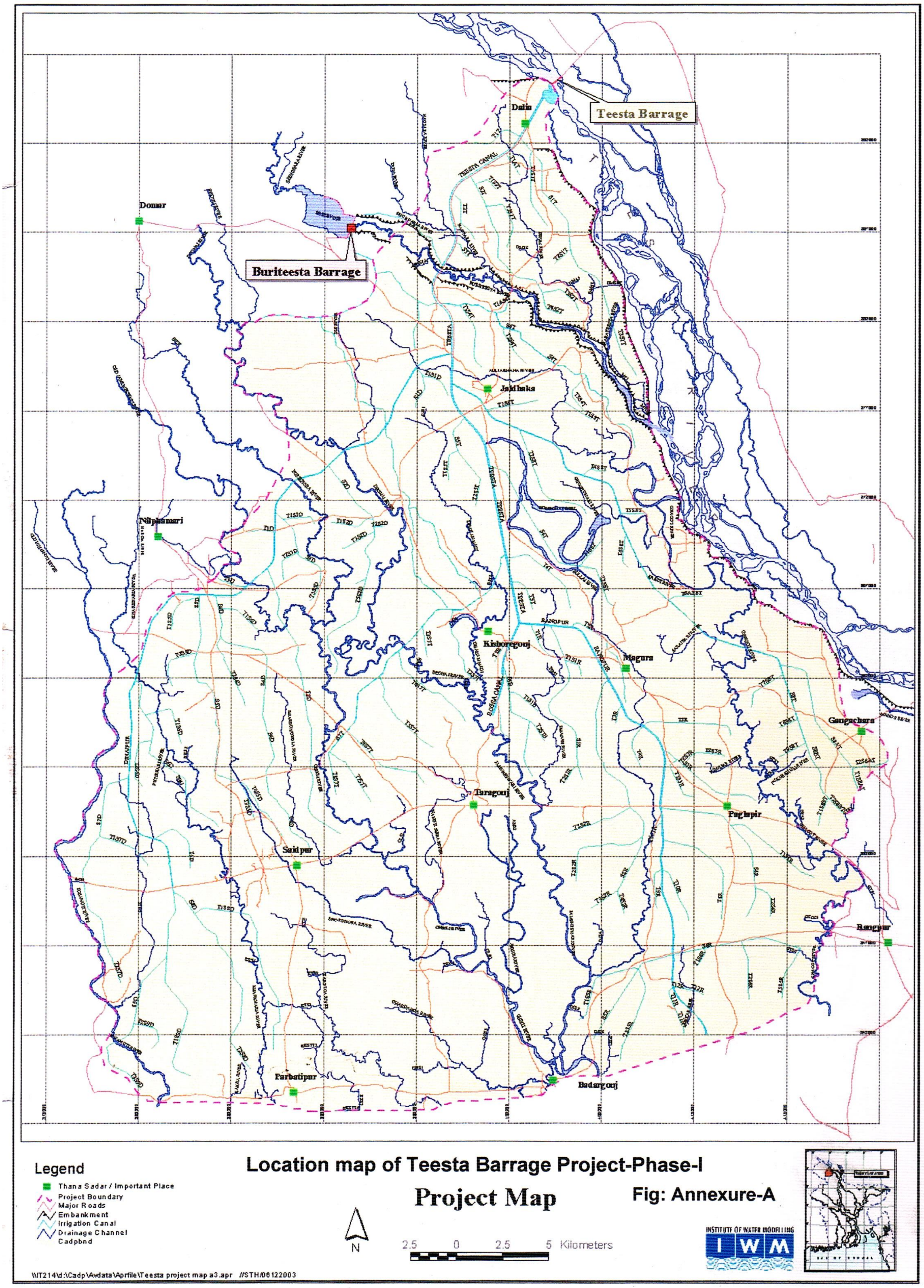

Figure 1.3 : Teesta Barrage Project Phase-I

Figure 1.4 Teesta Project Main Regulator

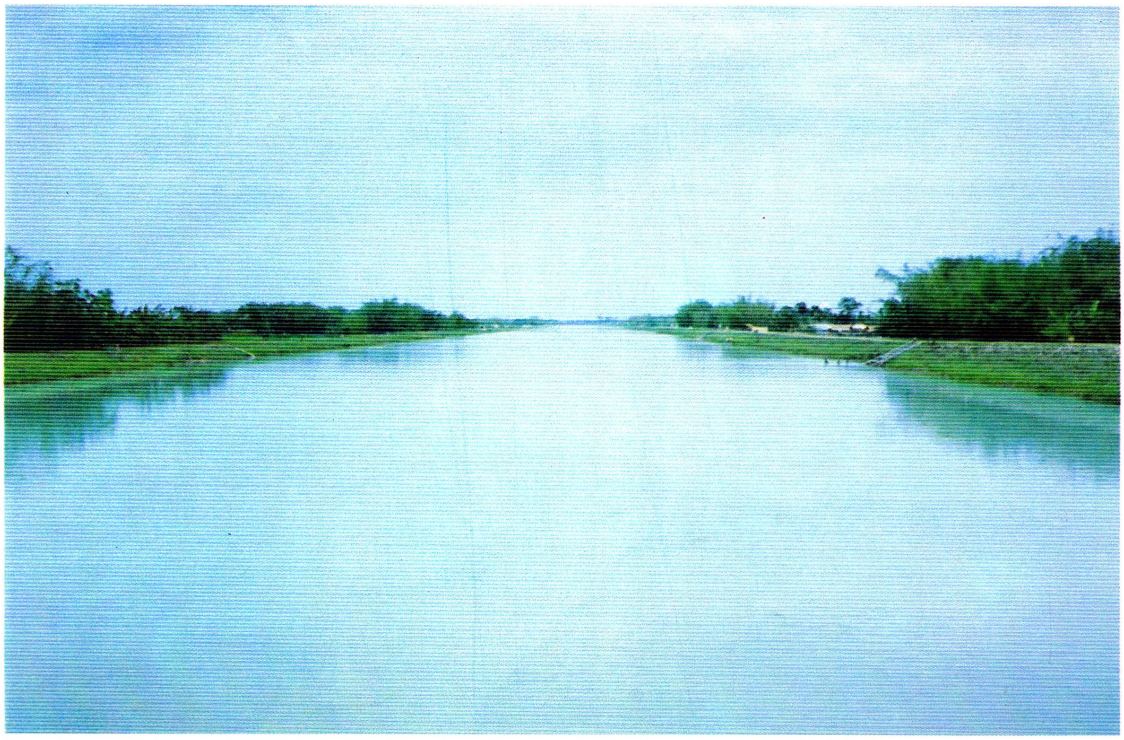

Figure 1.5 Teesta Main Canal

Figure 1.6 Tessta Project Secondary Canal

Figure 1.7 Tertiary Canal

Figure 1.8 Convey water over drainage Khal

Figure 1.9 Outlet with Paddy Field

1.6 Project Coverage Area

Table: 1.2 The Project area coverage the following districts and Upazilla

District	Upazilla
Rangpur	Rangpur
	Gangachara
	Badarganj
	Taraganj
Nilphamari	Nilphamari
	Jaldhaka
	Saidpur
	Dimla
	Kishoreganj
Dinajpur	Chirirbandar
	Parbatipur
	Khansama

1.7 People Participation and user Groups (Ref. PP)

Peoples Participation and user Groups

- People's participation in the policy matters and implementation of the policies of the command area development
- Formation of outlet committees and Tertiary/Secondary committees
- Participation of the people (beneficiaries) in the project activates-mobilization of the farmer groups and users groups of irrigation.
- Participation of the people in digging channels in the field for irrigation
- Farmers training on modern methods of irrigation and agriculture technology

- Demonstration plots establishment for practical orientation of the farmers about modern methods of farming.
- Estimated targets of benefits accrued during first phases of project :
- Additional crops yield per: Paddy and Wheat
- Income from additional crop production
- Employment generation during construction
- Employment generation during maintenance of the project
- Additional Employment of farm laborers per year
- Gravity food production

1.8 Command Area Development (CAD) (Ref. PP)

- Command area Development is the key to success of any irrigation project. Best use of available water and optimization of irrigation area could be achieved through proper implementation and also through monitoring of command area development activities. An amount of TK. 200.00 lakh was provided in the PP for command area development program to be executed within June, 1997.
- Availability and use of irrigation water had the potential for accelerated agricultural activities, for which the were trained and educated in the technique of water management to maximize water use efficiency. Following activities were undertaken to achieve the same.

✓ Strengthen existing irrigation groups and from new irrigation groups.

- ✓ Irrigation water distribution efficiently up to plot level through lined and unlined earthen field channels with control outlets.
- ✓ Farmers training in operation and maintenance of distribution system and field level water management.
- ✓ Irrigation groups leaders training in the operation of outlets.
- ✓ Research results on water management under intensive irrigated agriculture transmitted to farmers through agricultural extension services.

1.9 Assumptions of net project benefits or outcome (Ref.PP)

- Income distribution: Due to the project, assurance of income for the landowners by increasing crop production and to the marginal and landless farmers by creation of employment opportunities.
- Cost effectiveness of domestic resource utilization: Since the project involved labour intensive works, surplus labour force in the project area, were utilized during the construction and after completion of the project. Local construction materials like stone shingles, sand, bricks, bamboo etc. Use of unskilled labour at cheaper rates and utilization of domestic resources kept the development cost of the project low.
- Impact on environment and ecology: Provision of flood protection and drainage improvement due to the project supposed to have positive impacts on the physical environment of the area. Improvement of communication facilities due to flood control measures; incidence of water borne diseases reduction. The project was expects to achieve a

better hydrological balance in the rivers and canals in the project area and thereby better ecological balance maintained.

Table 1.3 Year wise target and achievement of irrigation area (ha) during the period of 1993-1994 to 2010-2011

Year	Target kharif-II (Aman Season) & kharif-I (Aus Season)	Achievement kharif-II (Aman Season) & kharif-I (Aus Season)	Percentage
1993-1994	15000	11400	78
1994-1995	15000	8676	58
1995-1996	12000	8890	74
1996-1997	12000	8317	69
1997-1998	40000	36000	90
1998-1999	40000	12230	31
1999-2000	40000	17975	45
2000-2001	73749	43650	59
2001-2002	64274	75634	118
2002-2003	105045	85129	81
2003-2004	99548	99710	100
2004-2005	119278	127426	107
2005-2006	141000	141100	100
2006-2007	123250	121041	98
2007-2008	97198	80252	83
2008-2009	85993	63648	74
2009-2010	86893	82021	94
2010-2011	82200	27213	33

Source: Chief Engineer's Office, Northern Zone, BWDB, Rangpur Irrigation coverage during kharif-I (dry) season indicates that irrigation achievement is less than irrigation target. This is quite logical as the project was originally designed for supplementary irrigation during kharif-II (monsoon) season; whatever irrigation coverage has been achieved during kharif-I (dry) season is an additional advantage to the project people. Moreover, the entire irrigated area achieved during kharif-I (dry) season was under HYV rice cultivation, which further contribute to increased crop production and thereby increased income of the farmers as well as socio-economic condition. Democratic spirit has been followed in the formation of WMGs and WMAs in TBP and the representation of all categories of local stakeholders is these groups and associations. Achievement of formation of all groups and associations is 1756 against targets of 2000. On the other hand the formation of WMAs has exceeded target from 52 to 60. One WMF has been formed as per GPWM (Group) Participation in Water Management). Irrigation service change collection is not satisfactory.

1.10 External Evaluation and Recommendation

Despite the recent positive impact on agricultural income and employment opportunities, the following observations are put forward to ensure long-term benefit of Tessta Barrage project. Yearly target of service change collection is not achieved. WMA is responsible for collection of service charge. Local bad elements and influential do not pay their service charges, but the farmers pay their service changes regularly. If service charges are deposited in designated banks by the designated officials of WMAs and proper account thereof is kept, then doubt and confusion of the beneficiaries will no longer be there. Faith and confidence will be established gradually. The guideline should be established and circulated among the WMAs and farmers with instruction for meticulous adherence to the principles laid therein.

- Repair of canal dykes are some times carried out during supply of irrigation water. Under this situation the quantity and quality of repair work cannot be ascertained. After detailed investigation, repair work should be completed between November and December. As such, there will be no problem to supply irrigation water at the tail end. Steps should be taken so that water reaches to all section during dry season & also misuse of water at any place should be reduced.

- Poverty alleviation: During execution about 387.00 Lake man-days's of construction labor and during operation about additional 100.47 lake labor were employed. New employment generated additional income to the poorer section of the rural population and to this extent poverty was alleviated.

Impact on Woman Development: On completion of the project, the accelerated agricultural activities in the project area offered partial employment to women on home-based activities and agro-based cottage industries. Women folk in the project area belonged to farm families and they participated in agricultural activities at family level

1.11 Some studies on Tessta Barrage Irrigation Project

Water resources project like Teesta Barrage Project is necessary for the development of a nation. The successful implementation of the Teesta Barrage Irrigation Projects was dream comes true for them. The poverty stricken people could now hope for a better future. Based on the above discussion, the major findings of the study can be summarised as below;

There is no significant change of temperature due to implementation of the project, whereas a significant change in rain fall pattern was observed. There is a minor change in humidity but remarkable change is observed in evaporation. Proper use of surface water available in Teesta Barrage catchment area is the best option, which would enable the farmers to use cheaper irrigation water that would also be environment-friendly (Sarker et al, 2011)

Teesta River was the principal tributary of the Karatoya-Atrai-Jamunaswari river system in the eastern part of India until late eighteenth century (BWDB 1999). The river originates in the glaciers of the Himalayes in Sikkim. It flows about 172 km in mountainous region before emerging into the alluvial plains of north Bengal in India. The river crosses 97 km in Indian plains before it enters into the extreme northwest region of Bangladesh. If flows about 124 km in Bangladesh and joins Brahmaputra River. The river changed its course and is now recognized as an unstable, wandering and young river of the country. The present channel within Bangladesh is about 177 km and width varies from 300 to 550 m. Bangladesh occupies about 2071 km^2 or 17% of the total Teesta catchment area.

The Teesta River Floodplain (TRF) in Bangladesh accounts for 14% of the total cropped area and 8.5% of the population in the country (BBS 2001). About 63% of the total cropped area in the TRF is irrigated as compared to the national average of 42% irrigated cropped land. On average, each unit of this irrigated cropped land supports 1.82 crops per year as compared with national average of 1.75 crops per year. This indicated a direct association between irrigation water availability and land use. About 64% of the total households in the TRF are farms, of which 78% are marginal or small, owning less than 1.0 ha of cultivated land (Census of Agriculture 1996). The northwestern region, which includes the TRF, if considered to be the most drought-prone area of the country (Murshid, 1987). This region along the left bank of the Ganges River is termed as 'dry zone' (Brammer, 1997). The mean annual rainfall, which ranges from 1250 mm to 2000 mm, in this area is much lower compared with 1600 mm to more than 5000 mm in the other regions of the country.

1.12 Aim of the Study

To study the impact of Teesta barrage on the different environmental components in command area

1.13 Objectives of the Study

1. To study the impact of Teesta Barrage on groundwater table in project area,
2. To study the impact of Teesta Barrage on rainfall
3. To study the impact of Teesta Barrage on agriculture, and
4. Finally to study the impact of Teesta Barrage on drinking water availability, social forestry and disease incidence in the project area.

1.14 Study Area

1.14.1 Location of study Area

This study was conducted in three upazillas of Dimla, Jaldhaka and Kishoregonj of Nilphamari district Figure (1.10) district consist of six upazillas. It is a part of Rangpur Division. Dimla upazilla is the north border, on the south upazilla is Jaldhaka, on the south of Jaldhaka upazilla is Kishorgong upazilla under Nilphamari district.

1.14.2 Crops cultivation in study Area

Main crops are paddy, jute, wheat, potato, corn, mustard, pulses, tobacco, Extinct or nearly extinct crops are aus paddy, jute, broadcasted aman and pulses in study area.

1.14.3 Land Type in study Area

The soil composition is mainly alluvial soil, 80% of the Teesta River basin and the remaining is barind soil.

1.14.4 Land use

The gross area of (TBP) is 750,000 ha (=7,500km^2). of which 540,00 ha are devoted for irrigation areas.

1.14.5 Climate of study area

The temperature rang from 32^{0}C to 11^{0}C and average annual rainfall is 1257.2 mm.

1.14.6 Rivers of study Area

Buri teesta flows over Dimla, Jaldhaka and Kishorgonj upazilla main River is Tessta (Figure 1.10).

Figure 1.10 Map of Study area

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Chapter 2
Effect of Teesta Barrage Irrigation Project on Ground Water Table

2.1 Introduction

Bangladesh is predominantly an agricultural country. Development of the economy of Bangladesh is dependent on the development of agriculture. Irrigation plays a vital role for more production of food. Ground water irrigation is the most essential input for increasing crop production as well as for the sustainable agricultural development. Availability of ground water for irrigation has contributed to manifold increase in crop productivity in Bangladesh. Increasing population, food security, growing economies and poor water management are putting unprecedented pressure on the world's fresh water resources (UNCSD, 2012). Ground water irrigation has probably been the most dramatic development in Bangladesh agriculture during the past 25 years. The ground water development project in Dinajpur district was initiated in 1962 with installation of 381 deep tube-wells. In 2004, 6047 DTWs, 70,000 STWs and other mode of irrigation were used in this area, which covers almost 57% of the total irrigable area (BMDA, 2006). Although the ground water dominates the total irrigated area, its sustainability is at risk in terms of quantity in the northwest region

(Simonovic 1997 and Shahid 2011). Different studies have documented that groundwater level declined substantially during the last decade causing threat to the sustainability of water use for irrigation in this region and impacting upon other sectors too (Jahan et al., 2010). Frequent shortage of water in the region has had impacts that can be ranged as economical, social and environmental (Takara and Ikebuchi, 1997; Sajjan et al., 2002 and Dey et al., 2011). A recent study shows that groundwater level in some areas falls between 5-10 m in dry season and most of the tube-wells fail to lift sufficient water (Dey and Ali, 2010).

Teesta Barrage Irrigation Project (TBIP) was started in 1994 to provide supplementary irrigation facility to T-aman crop during kharif season in greater Rangpur, Boagra and Dinajpur districts through divert of water from Teesta river with many canals. This TBIP project has also constructed many embankments to protect the command area from flood water of Teesta. Therefore, this study was carried out to study the impact of Teesta Project on the ground water table in the command area.

2.2 Objective of the study

To study the impact of Teesta Barrage Irrigation Project on ground water table in the command area of this project.

2.3 Data collection and analysis

2.3.1 Data collection

The study is based on analysis of secondary data. Secondary data on ground water table was collected from various agencies as. Bangladesh Water Development Board (BWBD) and Teesta Barrage Monitoring Office, Dalia Lalmonirhat.

2.3.2 Data Categorization

Ground water (1982-2005)) data were divided into two periods as per season for six seasons of Bangladesh in this way each season consists of two months:

Summer	: 14 April to 14 June.
Rainy	: 15 June to 15 August
Autumn	: 16 August to15 October
Late	: 16 October to 14 December
Winter	: 15 December to 12 February and
Spring	: 13 February to 13 April

2.3.3 Data Analysis

In the present study, for the detection of a trend, time series data of ground water table was examined in three ways.

(a) Linear regression analysis

(b) Paired-samples t-Test

(c) Test of significance for trend

2.3.3.1 Linear Regression Analysis

Long term trends were identified by fitting a linear regression line to the data series data of ground water table. Trend was then identified by the slope parameter of the respective regression line. Linear regression line was drawn by using the least square method. The method was also used to find the mathematical equation of an appropriate trend line or trend curve. The least squares line approximating the set of points (x_1, y_1) (x_2, y_2).......... (x_n, y_n) had the equation = $a_0 + bx$.

Where a_0 was the intercept and b was the slope of the regression line. Constants 2 a_0 and b determined by solving simultaneously the equations.

$$\sum y = a_0 + b\sum x$$

$$\sum xy = a_0 \sum x + b \sum x^2$$

which are called the normal equations for the least squares line.

The constants were

$$a_0 = \frac{\left(\sum y\right)\left(\sum x^2\right) - \left(\sum x\right)\left(\sum xy\right)}{N\sum x^2 - \left(\sum x\right)^2}$$

$$b = \frac{N\sum xy - \left(\sum x\right)\left(\sum y\right)}{N\sum x^2 - \left(\sum x\right)^2}$$

2.3.3.2 Student's t-Test

Comparison of two period means was carried out by using parried-samples t-test. A significant change in ground water table was judged by comparing two periods mean for the chosen parameters. Two time periods 1983-1993 and 1994-2004 for ground water table were performed to compare the means between two groups of samples. Here the t-test was performed to see whether or not the mean of parameters had significantly changed between the two time periods in the above parameters. Usually, t-test is employed in this type of analysis.

The t-test is the most widely used one for comparing means of any two independent groups of data. The hypothesis to be is as follows.

$H_0 : \mu_i = \mu_j$ When i = 1 then j = i + 1

$H_1 : \mu_i \neq \mu_j$ i = 2 then j = i + 1

i = 3 then j = i - 2

Where i = 1, 2, 3; i. period-1, period-2, period-3, respectively and μ is the mean of ith period.

The test statistic is computed as

$$t = \frac{\overline{\mu}_i - \overline{\mu}_j}{s_{p_i}}$$

In which t is the value of a random variable having a t-distribution with v = $n_1 + n_1 - 2$ degree of freedom; n_1 is the sample sizes of ith period s_{p_1} is the standard error which is given

$$S_{pi} = \frac{(n_i - 1)s_i^2 + (n_j - 1)}{n_i + n_j - 2}\left(\frac{1}{n_i} + \frac{1}{n_j}\right)^{0.5}$$

In which S²i is the sample variances of ith period.

$$\text{If} \quad |t| < t_{\alpha/2}$$

The null hypothesis H_0 is accepted which means that the difference of any two periods is not significant at significance level∝. The mean value of three periods of every season and t-test result for ground water and were presented below in Table 3.1 and 3.2 respectively.

2.3.3.3 Significance of Trend

In order to test Significance of the slope of the regression equation the flowing hypothesis is tested

$$H_0 : b_0 = 0.0$$
$$H_1 : b_0 \neq 0.0$$

The test statistic is calculated as follows:

$$t = \frac{(b - b_0)}{s / \sqrt{sxx}}$$

where b is the computed slope, b_0 is the hypothesized slope (zero in this case), S is the standard error of estimate given by

$$s = \sqrt{\frac{s_{yy} - bs_{xy}}{n - 2}}$$

In which

$$s_{yy} = \sum_{i=1}^{n} (y_i - \bar{y})^2$$

$$s_{xy} = \sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})$$ s

and $$s_{xx} = \sum_{i=1}^{n} (x_i - \bar{x})^2$$

Null hypothesis H_0 is rejected if $|t| \geq t_{1-a} / 2, n-2, a$ is the level of significance and n-2 is the degree of freedom.

2.4 Results and Discussion

An attempt was made to study the changing pattern of seasonal mean data of ground water table. Twenty two years (1983-2004) data was divided into two 11 years periods for six Bengali seasons of Bangladesh. Linear regression lines were filled to the data series of two eleven year's period of groundwater table. The vertical and horizontal axes represented groundwater level in meter and year, respectively. Each of the data series of ground water exhibited period to period variation.

Summer

Figure 2.1 and Table 2.1 show that ground water table after the Teesta Barrage Irrigation Project (1994-2004) was improved than the pre-project period (1983-1993) during summer season. The mean value of ground water table in pre-project scenario was 2.59 m but it came to at 1.39 m in post-project period (Table 2.A1 in Appendix). The mean difference of ground water table of these two periods was significant as per t-test (Table 2.A2 in Appendix). Therefore, Teesta Barrage Irrigation Project has positive impact on the restoration of falling ground water table in the study area.

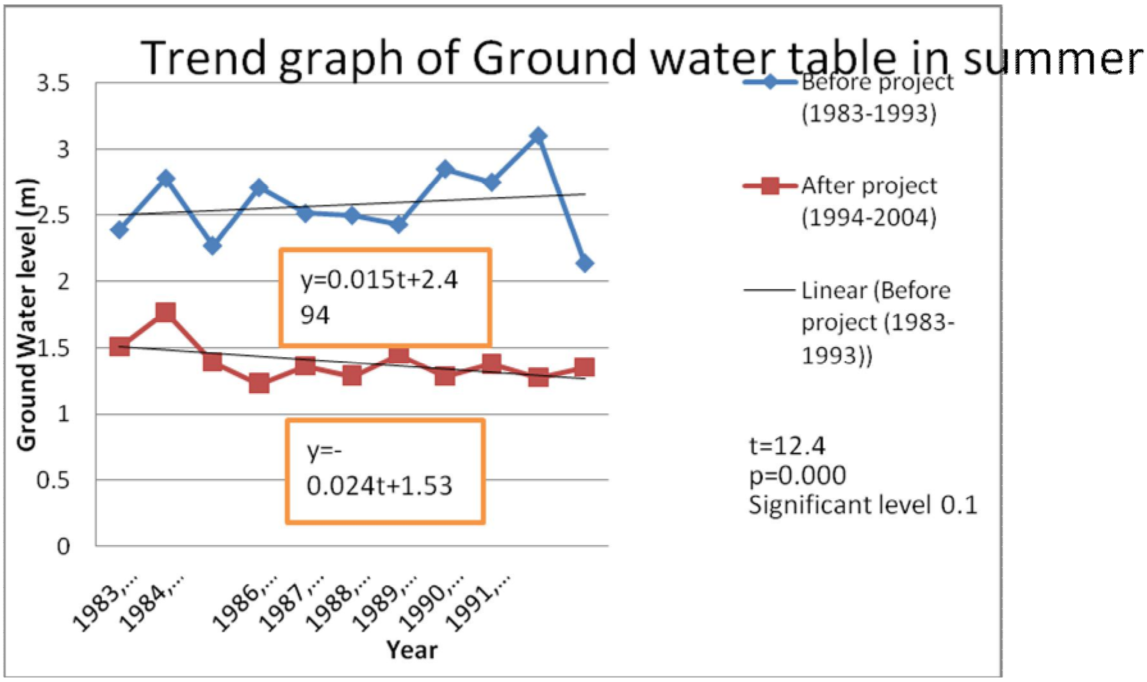

Figure 2.1: Trend graph of Ground water table in Summer season

Table 2.1: Estimated value of t-statistics for slope and p-value for different regression equations for Ground water table in summer season

Data series	No. of observ:	Regression equation	T-Statistics for slope	P-Value	Remarks (change)
Period-1 1983-1993	11	y= 0.015t+2.494	3.4	0.003	(+)**
Period-2 1994-2004	11	y= -0.024t+1.534	4.6	0.000	(-)***

From the Table 2.1 it is observed that slope parameters of equation-2 for seasonal trend of ground water table in summer season was statistically significant at 0.01% level and non zero with negative sign and equation-1 was statistically significant at 1% level and non zero with positive sign of equation -1 that show upward trend in 1st period. Equation-2 shows downward trend in 2nd period with negative sign. That means, ground water table was found to have decreasing and increasing trends with time change but the rate of increasing and decreasing of ground water table were 0.015m/month in period-1 and 0.024m/month in period-2. The value of slope parameter of equation -2 was maximum and the value of slope parameter of equation-1 was minimum. It proves that the rate of increasing was less in period-1 and rate of decreasing was more in period-2.

Rainy

As like as summer, the ground water table was found to improve during rainy season in post-project scenario (1994-2004) than the pre-project period (1983-1993) in rainy season (Figure 2.2 and Table 2.2). Teesta Barrage Irrigation Project continuously provides irrigation facilities during rainy season to T-aman field. Therefore, surface water gets more time to infiltrate into groundwater and resulting groundwater level gets up in project area. In rainy season, the mean value of ground water level in pre-project scenario was 1.56 m but it came to at 1.23 m in post-project period (Table 2.A1 in Appendix). The mean difference of ground water table of these two periods was statistically significant as per t-test (Table 2.A2 in Appendix).

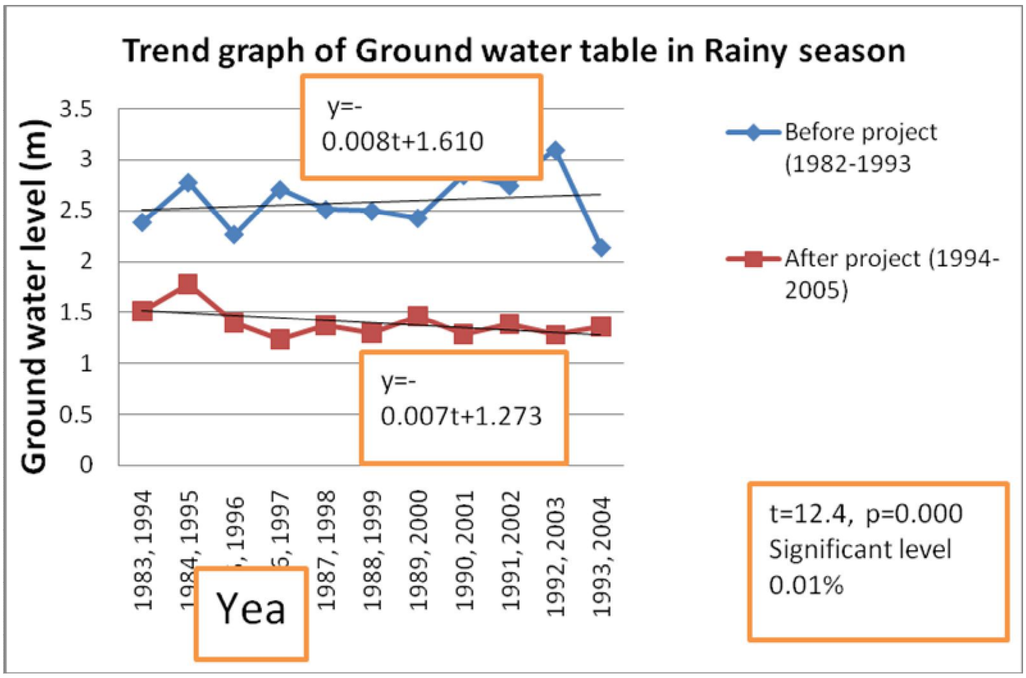

Figure 2.2: Trend graph of Ground water table in Rainy season

Table 2.2: Estimated value of t-statistics for slope and p-value for different regression equations for ground water table in Rainy season

Data series	No. of observation	Regression equation	T-Statistics for slope	P-Value	Remarks (change)
Period-1 1982-1993	11	y= -0.008t+1.610	4.44	0.000	(-)***
Period-2 1994-2005	11	y= -0.008t+1.273	4.77	0.000	(-)***

Table 2.2 reveals that the slope parameters of two equations for seasonal trend of ground water table during Rainy season were statistically significant at 0.01% level and non zero with negative sign that show downward trend in both pre- and post-project periods. That means, ground water table was found to have decreasing trends with time change but the rate of decreasing of ground water table was 0.008m/month for both of the periods. The value of slope parameter of equation -1 and equation-2 was equal. It proves that the rate of decreasing period-1 and period-2 was equal.

Autumn

Likewise summer and rainy seasons, the ground water table was also found to improve during autumn season in post-project scenario (1994-2004) than the pre-project period (1983-1993) (Figure 2.3 and Table 2.3). Teesta Barrage Irrigation Project also provides irrigation facilities in autumn to T-aman field, hence, upward groundwater table is found. During autumn, the mean value of ground water level in pre-project scenario was 1.65 m but it came to at 1.30 m in post-project period (Table 2.A1 in Appendix). The mean difference of ground water table of these two periods was statistically significant as per t-test (Table 2.A2 in Appendix).

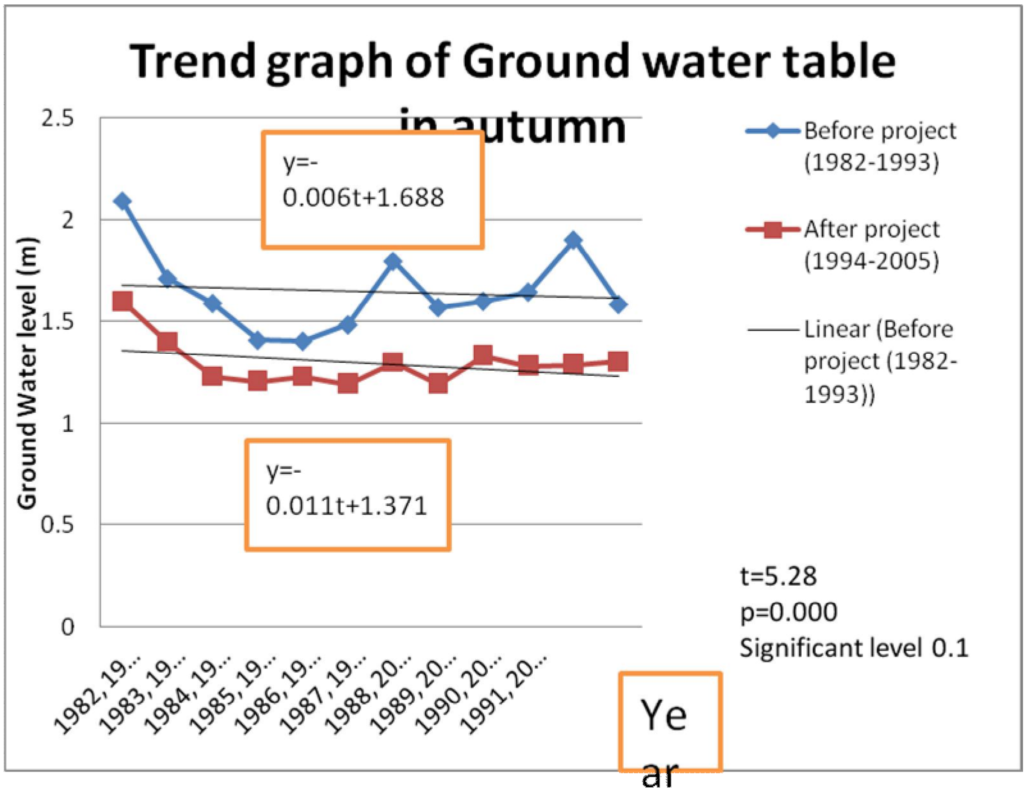

Figure 2.3: Trend graph of Ground water table in Autumn season

Table 2.3: Estimated value of t-statistics for slope and p-value for different regression equations for Ground water table in autumn season

Data series	No. of observation	Regression equation	T-Statistics for slope	P-Value	Remarks (change)
Period-1 1982-1993	11	y= -0.01t+1.688	4.65	0.000	(-)***
Period-2 1994-2005	11	y= -0.011t+1.371	5.00	0.000	(-)***

From above Table 2.3 it is found that that the slope parameters of two equations for seasonal trend of ground water table during autumn season were statistically significant at 0.01% level and non zero with negative sign that show downward trend in two periods. That means, ground water table during autumn season was found to have decreasing trends with time change but the rate of decreasing of ground water table were 0.01m/month for period-1 and 0.011m/month for period-2. The value of slope parameter of equation -2 was maximum and the value of slope parameter of equation-1 was minimum. It proves that the rate of decreasing of ground water table was more in period-2 and less in period-1.

Late Autumn

As like as autumn, an improved groundwater level was found during post-project period (1994-2004) compare to pre-project (1983-1993) (Figure 2.4). Ground water level goes down in late autmun compare to autumn. In this season, ground water level in pre-project scenario was 2.46 m but this level gets up at 1.69 m in post-project period (Table 2.A1 in Appendix). A statistically significant difference is found between these periods in this season (Table 2.A2 in Appendix).

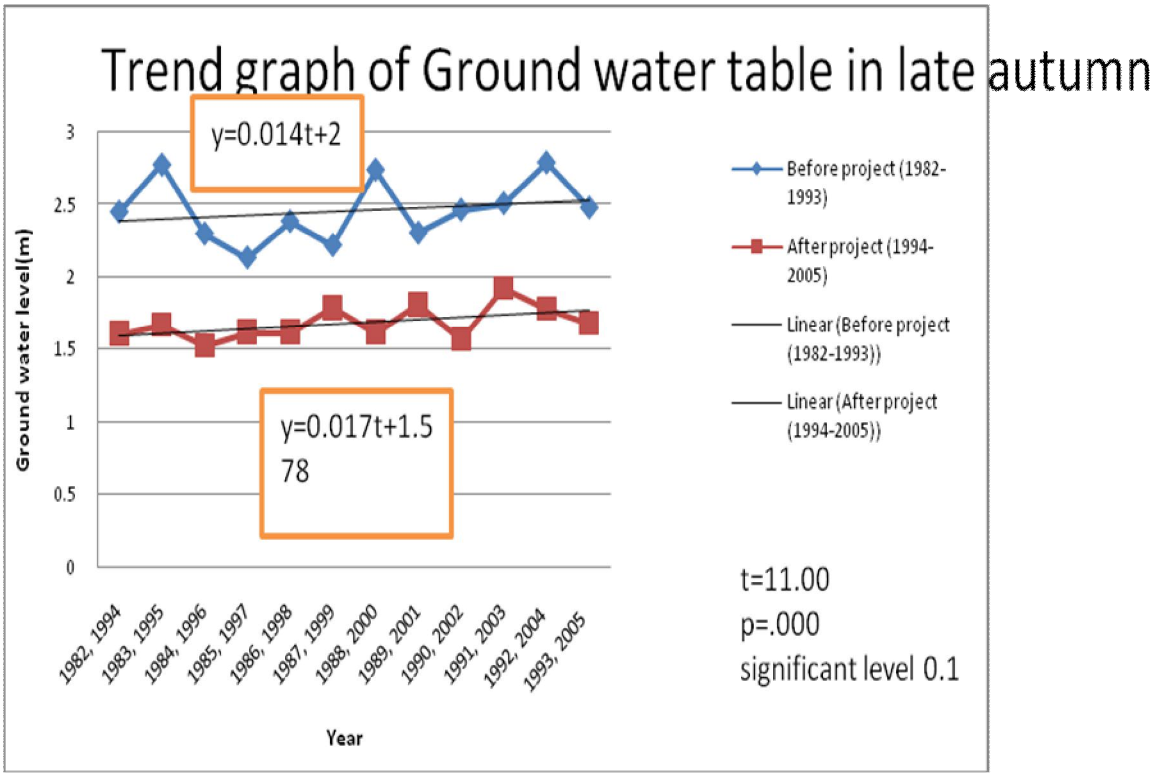

Figure 2.4: Trend graph of Ground water table in late Autumn season

Table 2.4: Estimated value of t-statistics for slope and p-value for different regression equations for Ground water table in late autumn

Data series	No. of observation	Regression equation	t-Statistics for slope	P-Value	Remarks (change)
Period-1 1982-1993	11	y= 0.014t+2.375	3.87	0.000	(+)***
Period-2 1994-2005	11	y= 0.017t+1.578	4.62	0.000	(+)***

From above table 2.4 we can see that the slop parameters of two equations for seasonal trend of ground water table during late autumn season were statistically significant at 0.01% level and non zero with positive sign that show upward trend in both periods. That means, ground water table was found to have increasing trends with time change but the rate of increasing of ground water table was 0.014m/month in pre-project period (1982-1993) and 0.017m/month in post-project period (1994-2005). The value of slope parameter of equation -2 was maximum and the value of slope parameter of equation-1 was minimum. It proves that the rate of increasing was more in period-2 and less in period-1.

Winter

In winter, an improved groundwater level was found like other seasons during post-project period (1994-2004) compare to pre-project (1983-1993) (Figure 2.5). However, the differences of ground water table of these two periods are not high. In this season, ground water level in pre-project scenario was 2.83 m but this level gets up at 1.92 m in post-project period (Table 2.A1 in Appendix). A statistically significant difference is found between these periods in this season (Table 2.A2 in Appendix).

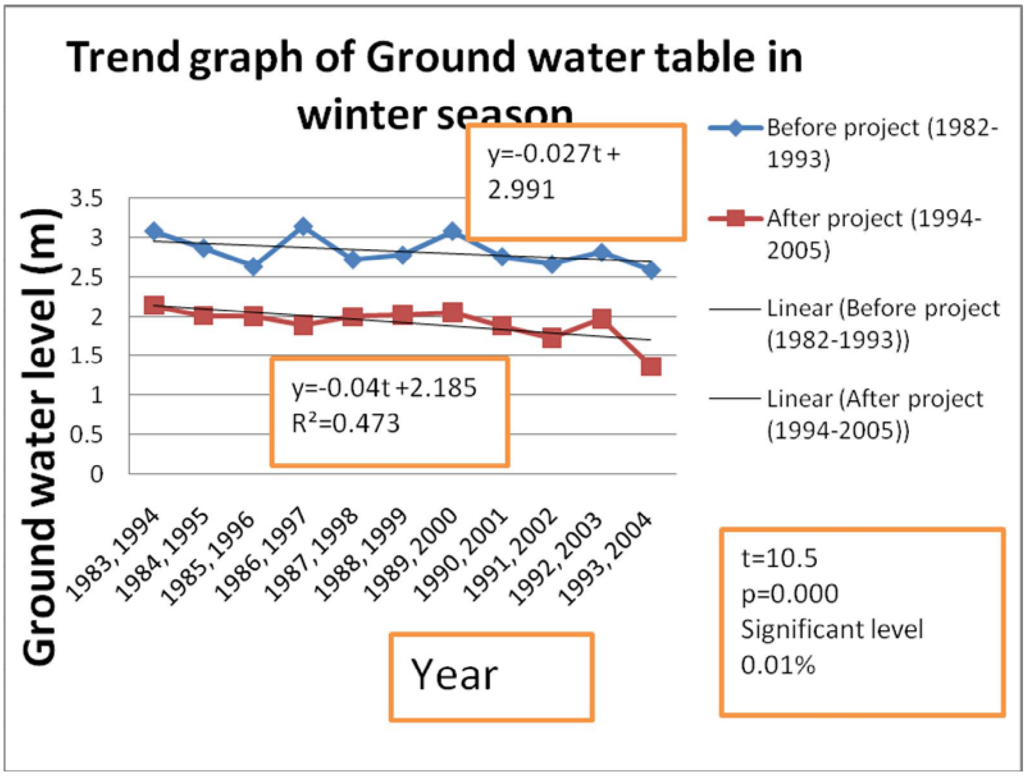

Figure 2.5: Trend graph of Ground water table in Winter season

Table 2.5: Estimated value of t-statistics for slope and p-value for different regression equations for Ground water table in winter season

Data series	No. of obse:	Regression equation	t-Statistics for slope	P-Value	Remarks (change)
Period-1 1982-1993	11	y= -0.027t + 2.992	3.17	0.005	(-)**
Period-2 1994-2005	11	y= -0.044t +2.186	4.07	0.000	(-)***

Table 2.5 reveals that the slope parameters of two equations for seasonal trend of ground water table during winter season were statistically significant at 1% level in pre-project period (1982-1983) and 0.01% level in

post-project period (1994-2005). Non zero with negative sign shows downward trend for both of the periods. That means, ground water table during winter season was found to have decreasing trends with time change but the rate of decreasing of ground water was 0.027m/month in period-1 and 0.044m/month in period-2. The value of slope parameter of equation -2 was maximum and the value of slope parameter of equation-1 was minimum. It proves that the rate of decreasing was more in period-2 and less in period-1.

Spring

Figure 2.6 and Table 2.6 show that ground water table after the Teesta Barrage Irrigation Project (1994-2004) was improved than the pre-project period (1983-1993) during spring season. The mean value of ground water level in pre-project scenario was 3.16 m but it reduced to 1.61 m in post-project period (Table 2.A1 in Appendix). The mean difference of ground water table of these two periods was significant as per t-test (Table 2.A2 in Appendix). Therefore, Teesta Barrage Irrigation Project has positive impact on the restoration of falling ground water table in the study area.

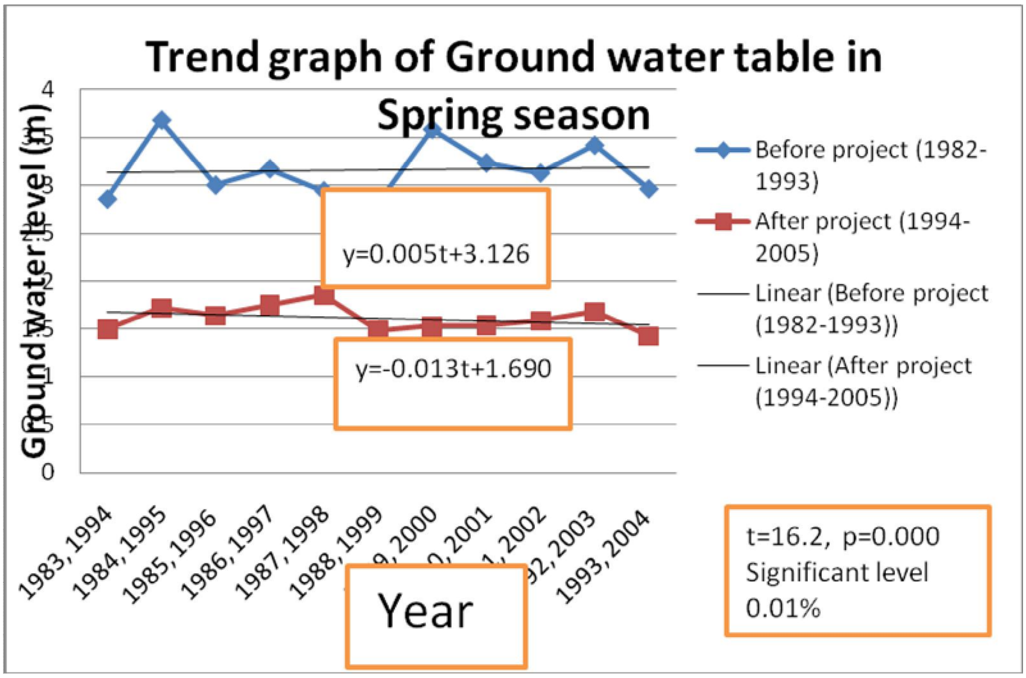

Figure 2.6: Trend graph of Ground water table in Spring season

Table 2.6: Estimated value of t-statistics for slope and p-value for different regression equations for Ground water table in spring season

Data series	No. of observation	Regression equation	t-Statistics for slope	P-Value	Remarks (change)
Period-1 1982-1993	11	y= 0.006t+3.127	2.83	0.01	(+)*
Period-2 1994-2005	11	y= -0.013t+1.690	4.39	0.000	(-)***

From above table 2.6 we can see that the slope parameters of equation-2 for seasonal trend of ground water table during spring season was statistically significant at 0.01% level having non zero with negative sign. But equation-1 was statistically significant at 1% level and non zero with positive sign shows upward trend in 1st period. Equation-2 shows downward trend in 2nd

period with negative sign. That means, ground water table in spring season was found to have both increasing and decreasing trends with time change but the rate of increasing was 0.006m/month in period-2 and rate of decreasing of ground water table was 0.013m/month in period-1. The value of slope parameter of equation -2 was maximum and the value of slope parameter of equation-1 was minimum. It proves that the rate of increasing was less in period-1 and more in period-2.

Monthly Groundwater Table of Average Years

Avearge montly data for 11-years was ploted in the graph for both pre-and post project periods. The goroundwater level in the post-project period was found to improve than the pre-project period in all over 12-months period (Figure 2.7). This graph proves that Teesta Barrage Irrigation Project is recharging the ground water level round the year.

The mean value of ground water level of monthly average in pre-project scenario was 2.37 m but it came to at 1.61 m in post-project period (Table 2.A1 in Appendix). The mean difference of ground water table of these two periods was significant as per t-test (Table 2.A2 in Appendix).

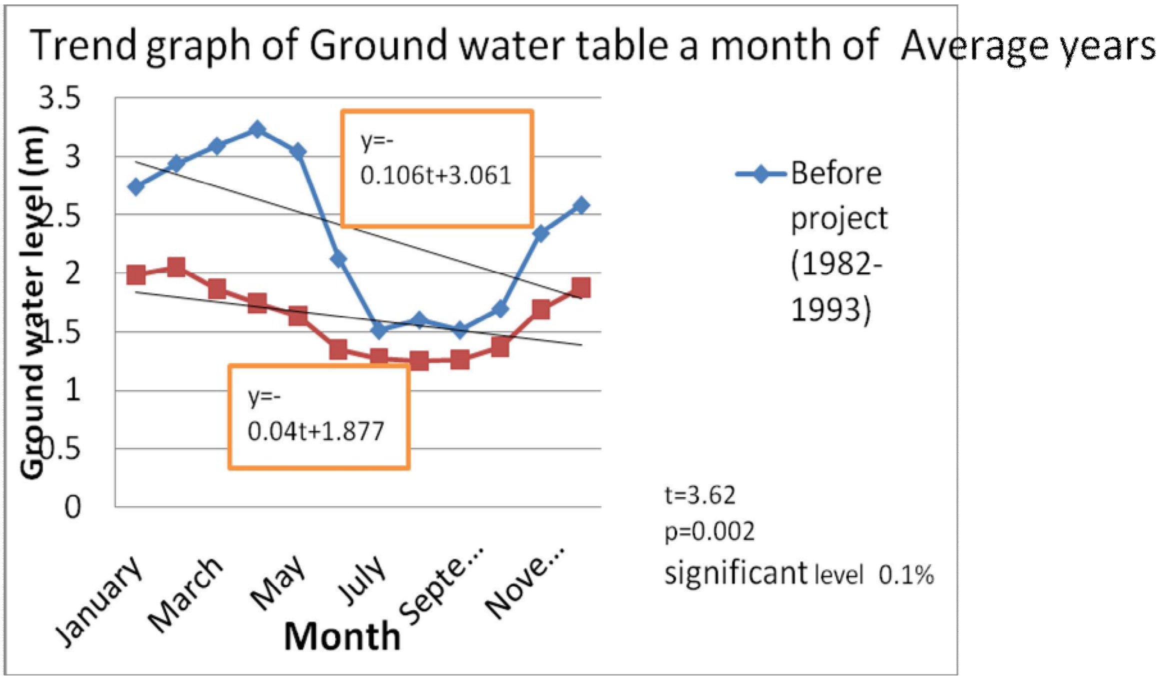

Figure 2.7: Trend graph of Ground water table in a month of average years

Table 2.7: Estimated value of t-statistics for slope and p-value for different regression equations for Ground water table in a month of average years

Data series	No. of observation	Regression equation	t-Statistics for slope	P-Value	Remarks (change)
Period-1 1982-1993	11	y= -0.106t+3.061	3.90	0.000	(-)***
Period-2 1994-2005	11	y= -0.041t+1.877	4.68	0.000	(-)***

Table 2.7 reveals that the slope parameters of two equations for seasonal trend of ground water table during a month of average years were statistically significant at 0.01% level and non zero with negative sign that indicated downward trend in both pre- and post-project periods. That means,

ground water table during a month of average years was found to have decreasing trends with time change but the rate of decreasing of ground water table was 0.106m/month in period-1 and 0.041m/month in period-2. The value of slope parameter of equation -1 was maximum and the value of slope parameter of equation-2 was minimum. It proves that the rate of decreasing was more in period-1 and less in period-2.

Groundwater Table of Average Years

Avearge yearly data for 11-years was ploted in the graph for both pre-and post project period. The goroundwater level in the post-project scenario was found upper than the pre-project period (Figure 2.8). This graph shows that Teesta Barrage Irrigation Project has improved ground water level in the study area.

The mean value of ground water level of monthly average in pre-project scenario was 2.35 m but it came to at 1.54 m in post-project period (Table 2.A1 in Appendix). The mean difference of ground water table of these two periods was significant as per t-test (Table 2.A2 in Appendix).

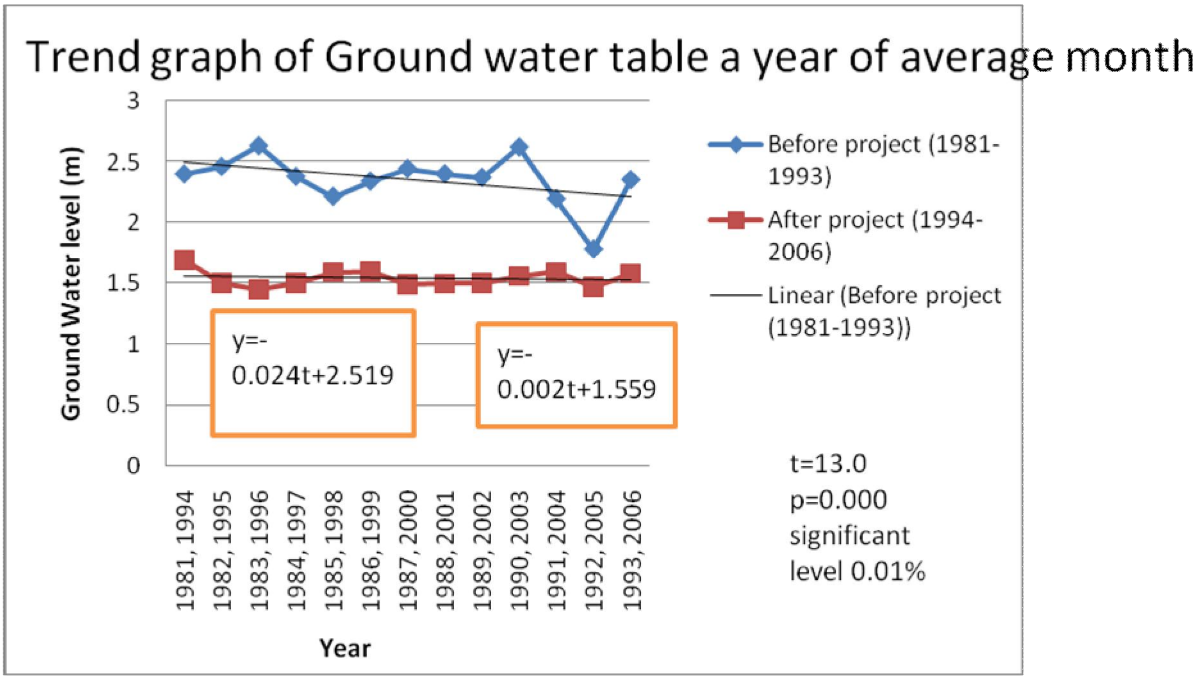

Figure 2.8: Trend graph of Ground water table in a month of average years

Table 2.8: Estimated value of t-statistics for slope and p-value for different regression equations for Ground water table in a year of average month

Data series	No. of obse:	Regression equation	t-Statistics for slope	P-Value	Remarks (change)
Period-1 1982-1993	11	y= -0.024t+2.519	4.30	0.000	(-)***
Period-2 1994-2005	11	y= -0.002t+1.559	5.05	0.000	(-)***

Table 2.8 reveals that the slope parameters of two equations for seasonal trend of ground water table during a year of average month were statistically significant at 0.01% level and non zero with negative sign that indicated downward trend in both periods. That means, ground water table during a

year of average month was found to have decreasing trends with time change but the rate of decreasing of ground water table was 0.024m/month in period-1 and 0.002m/month in period-2. The value of slope parameter of equation -1 was maximum and the value of slope parameter of equation-2 was minimum. It proves that the rate of decreasing was more in period-1 and less in period-2.

2.5 Conclusion

From this study, it is found that seasonal mean ground water table was up in post-project period (1994-2005) of Teesta Barrage Irrigation Project and level was down in pre-project period (1982-1993). The mean differences of ground water table of these two periods was significantly different (0.01% level) in all six seasons of summer, rainy, autumn, late autumn, winter, spring and summer. Therefore, it is concluded that Teesta Barrage Irrigation Project has positive impact on ground water resources and improved the ground water table in the command area.

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Appendix-Chapter: 2

Table 2.1: Mean value of two periods for Ground water table data series during six Bengali Seasons, a month of average years & a year of average month.

Parameter	Seasons	Period	
		1982-1993(1)μ_1	1994-2005(2)μ_2
Ground water	Summer	2.59	1.39
	Rainy	1.56	1.23
	Autumn	1.65	1.30
	Late autumn	2.46	1.69
	Winter	2.83	1.92
	Spring	3.16	1.61
	A month of average years	2.37	1.61
	A year of average month	2.35	1.54

Table 2.2: Results of t-test showing the mean difference between two periods of Ground water during six Bengali seasons, a month of average years & a year of average month.

Parameter	Seasons	Period	t-Statistic	P-value	Significance level (%)
Ground water	Summer	(1982-1993)& (1984-2005)	12.4	0.000	0.1
	Rainy	(1982-1993)& (1984-2005)	5.92	0.000	0.1
	Autumn	(1982-1993)& (1984-2005)	5.28	0.000	0.1
	Late autumn	(1982-1993)& (1984-2005)	11.00	0.000	0.1
	Winter	(1982-1993)& (1984-2005)	10.5	0.000	0.1
	Spring	(1982-1993)& (1984-2005)	16.2	0.000	0.1
	A month of average years	(1982-1993)& (1984-2005)	3.62	0.002	1
	A year of average month	(1982-1993)& (1984-2005)	13.00	0.000	0.1

Chapter 3
Effect of Teesta Barrage Irrigation Project on Rainfall

3.1 Introduction

Development of the economy of Bangladesh dependents much on water management including its use and distribution. Water resource development is linked with the accelerated process of transformation of agriculture through flood control, drainage and irrigation. Water recourses in Bangladesh is characterized by a dichotomy -abundance of water during monsoon and scarcity during winter (Rabi) season. Therefore, the central strategy for water resources development is expansion, coverage and water control measures to improve agricultural productivity and employment. The specific sectoral objectives of water resources development are:

- ❖ Rapid increase of irrigated area to accelerate the process of technological transformation;
- ❖ To provide supplementary irrigation facilities along with complementary FCD facilities in consonance with other resources to bring improvement in crops, yields and production during the kharif season;
- ❖ To provide timely and dependable supply of irrigation water in order to achieve crop production targets;

- To regulate and control floods and drainage, salinity, tidal water inundation and river erosion.
- To promote efficient use of water resources with respect to time and spatial location through emphasis on inter basin water balance and optimal cropping patterns and without causing harmful environment effects, and
- To generate employment opportunities for rural people in order to ensure equitable distribution of benefits of development.

The living standard of the farmers of the Teesta Barrage Irrigation Project area prior to the project was very low due to fact that the soil of the project area being sandy type, it is very expensive to grow more food adopting modem technology based on scanty & sporadic rainfall during rabi and kharif seasons. So gravity irrigation diverting Teesta water by a Barrage has come into necessity. Bangladesh Water Development Board has implemented Teesta Barrage Irrigation Project to facilitate irrigation and flood control measures in Lalmonirhat, Rangpur and Dinajpur districts. It is assumed that this mega irrigation project has positive impacts on the rainfall pattern in these three districts for high rate of evaporation of irrigation water round the year.

Many authors of India and Bangladesh have carried out study on the rainfall pattern. Blanford (1886) was the first meteorologist to make extensive studies of Indian rainfall during British period. He analyzed 19 years (1867-1885) annual rainfall data for India as a whole but did not find any systematic trend. Sarker and Thapliyal (1988) and Thapliyal (1990) studied the long period (1875-1989) annual rainfall of India. This analysis of the data did not reveal any significant trend.

In Bangladesh, rainfall analysis (frequency, distribution, rainfall pattern, etc.) has been studied by a number of investigators and different projects. Matin and Ahmed (1983) studied the daily rainfall for estimating the intensity duration frequency relationship for the North-Eastern region and Ahmed (1986) studied the long duration extreme value rainfall data for the North-West region. Siddique (1993) analyzed the extreme value of rainfall data of some selected urban regions of Bangladesh. Warrick et al. (1994) studied the variations of temperature and rainfall over Bangladesh. Karmaker and Khatun (1994) studied the temporal and spatial distributions of mean monthly rainfall and its variability together with the spatial distributions of the probabilistic estimates of rainfall extremes over Bangladesh during the south-west monsoon season. Asian Development Bank (1994) studied the climate change in Bangladesh using data of the period 1948-1990. This study found an increasing trend of rainfall in Bangladesh. The rate of increase of rainfall is 0.19% per year.

The present study explored changing pattern of rainfall in the command area of Teesta Barrage Irrigation Project. This study carried out regression and statistical analysis of rainfall data to detect the changes of rainfall pattern over project period.

3.2 Objective of the study

To study the impact of Teesta Barrage Irrigation Project on rainfall pattern in the command area.

3.3 Data collection and analysis

3.3.1 Data collection

The study is based on the analysis of secondary data. Secondary data about rainfall was collected from Teesta Barrage Monitoring Office, Dalia, Lalmonirhat and Bangladesh Meteorological Department, Agargaon, Dhaka.

3.3.2 Data Categorization

Twenty years rainfall (1984-2003) data were divided into two 10-years periods for six Bengali seasons of Bangladesh in following way each season consists of two months:

Summer	: 14 April to 14 June
Rainy	: 15 June to 15 August
Autumn	: 16 August to 15 October
Late	: 16 October to 14 December
Winter	: 15 December to 12 February, and
Spring	: 13 February to 13 April.

3.3.3 Data Analysis

In the present study, detection of a trend of a time series data like rainfall was examined in three ways.

(a) Linear regression analysis

(b) Paired-samples t-Test

(c) Test of significance for trend

3.3.4 Linear Regression Analysis

Long term trends were identified by fitting a linear regression line to the data series of rainfall. Trend was then identified by the slope parameter of the respective regression line. Linear regression line was drawn by using the least square method. The method was also used to find the mathematical equation of an appropriate trend line or trend curve. The least squares line approximating the set of points (x_1, y_1) (x_2, y_2).......... (x_n, y_n) had the equation = $a_0 + bx.$

Where a_0 was the intercept and b was the slope of the regression line. Constants a_0 and b determined by solving simultaneously the equations.

$$\sum y = a_0 + b\sum x$$

$$\sum xy = a_0\sum x + b\sum x^2$$

which are called the normal equations for the least squares line.

The constants were

$$a_0 = \frac{\left(\sum y\right)\left(\sum x^2\right) - \left(\sum x\right)\left(\sum xy\right)}{N\sum x^2 - \left(\sum x\right)^2}$$

$$b = \frac{N\sum xy - \left(\sum x\right)\left(\sum y\right)}{N\sum x^2 - \left(\sum x\right)^2}$$

3.3.5 Student's t-Test

Comparison of Two period Means was carried out by using parried-Samples t-test. Variation of rainfall was detected by comparing two periods mean for the chosen parameters. Two time periods 1984-1993 and 1994-2003 for rainfall were performed to compare the means between two groups of samples. Here the t-test was performed to see whether or not the mean of parameters had significantly changed between the two time periods in the above parameters. Usually, t-test is employed in this type of analysis.

The t-test is the most widely used one for comparing means of any two independent groups of data. The hypothesis to be is as follows.

$H_0 : \mu_i = \mu_j$ When i = 1 then j = i + 1

$H_1 : \mu_i \neq \mu_j$ i = 2 then j = i + 1

i = 3 then j = i - 2

Where i = 1, 2,3; i. e period-1, period-2, period-3, respectively and μ is the mean of ith period.

The test statistic is computed as

$$t = \frac{\overline{\mu}_i - \overline{\mu}_j}{s_{p_i}}$$

In which t is the value of a random variable having a t-distribution with v = $n_1 + n_1 - 2$ degree of freedom; n_1 is the sample sizes of ith period s_{p_1} is the standard error which

is given

$$S_{pi} = \frac{(n_i - 1)s_i^2 + (n_j - 1)}{n_i + n_j - 2}\left(\frac{1}{n_i} + \frac{1}{n_j}\right)^{0.5}$$

In which S²i is the sample variances of ith period.

If $|t| < t_{\alpha/2}$

The null hypothesis H_0 is accepted which means that the difference of any two periods is not significant at significance level $\propto$. The mean value of three periods of every season and t-test result for rainfall was presented below in Tables 3.1 and 3.2, respectively.

3.3.6 Significance of Trend

In order to test Significance of the slope of the regression equation the flowing hypothesis is tested

$$H_0 : b_0 = 0.0$$
$$H_1 : b_0 \neq 0.0$$

The test statistic is calculated as follows:

$$t = \frac{(b - b_0)}{s / \sqrt{sxx}}$$

where b is the computed slope, b_0 is the hypothesized slope (zero in this case), S is the standard error of estimate given by

$$s = \sqrt{\frac{s_{yy} - bs_{xy}}{n - 2}}$$

In which

$$s_{yy} = \sum_{i=1}^{n} (y_i - \bar{y})^2$$

$$s_{xy} = \sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})$$ s

and $$s_{xx} = \sum_{i=1}^{n} (x_i - \bar{x})^2$$

Null hypothesis ho is rejected if $|t| \geq t_{1-a} / 2, n-2, a$ is the level of significance and n-2 is the degree of freedom.

3.4 Results and Discussion

An attempt was made to study the changing pattern of seasonal mean rainfall using 20 years data series (1984-2003) of Teesta Barrage Irrigation Project. These data were divided into two 10 years periods (before project: 1984-1993 and after project: 1994-2003) according to six Bengali seasons of Bangladesh. Linear regression lines were filled to the data series of these two periods of rainfall. The vertical and horizontal axes represented rainfall in millimeter and year, respectively. Significant test of mean rainfall of two periods was done by t-test. Both linear regression analysis and t-test result on rainfall are presented season wise in this section.

3.4.1 Results

Regression Analysis of Trend of Rainfall

Trend analysis of mean rainfall for two periods (before and after Teesta project) was done as per six Bengali seasons and shown in graphs below:

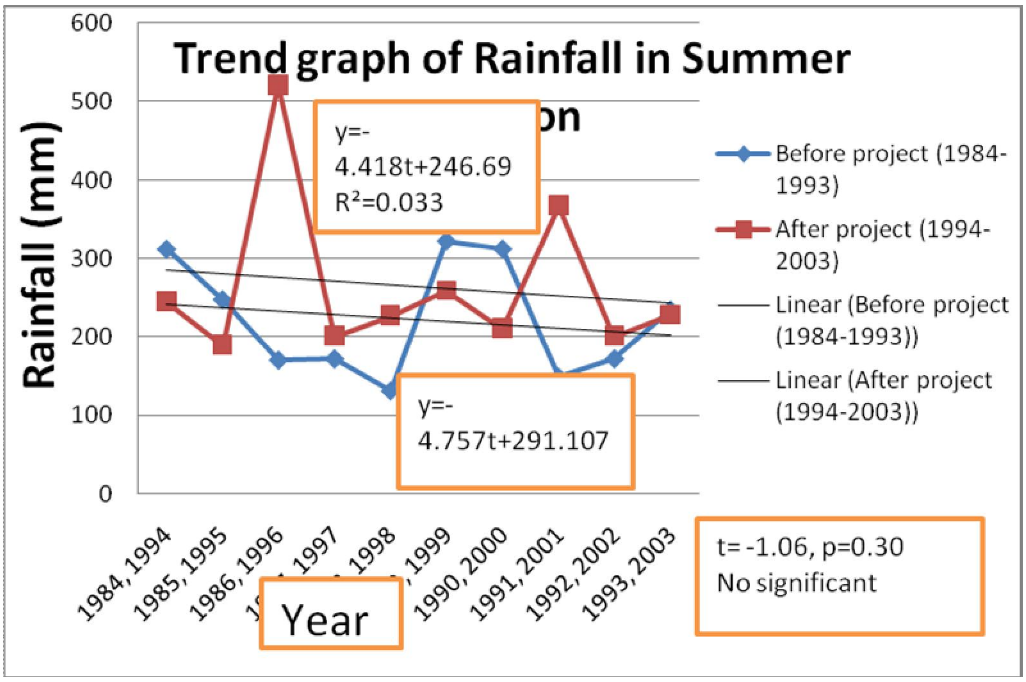

Figure 3.1: Trend in seasonal mean rainfall during summer for before and after project

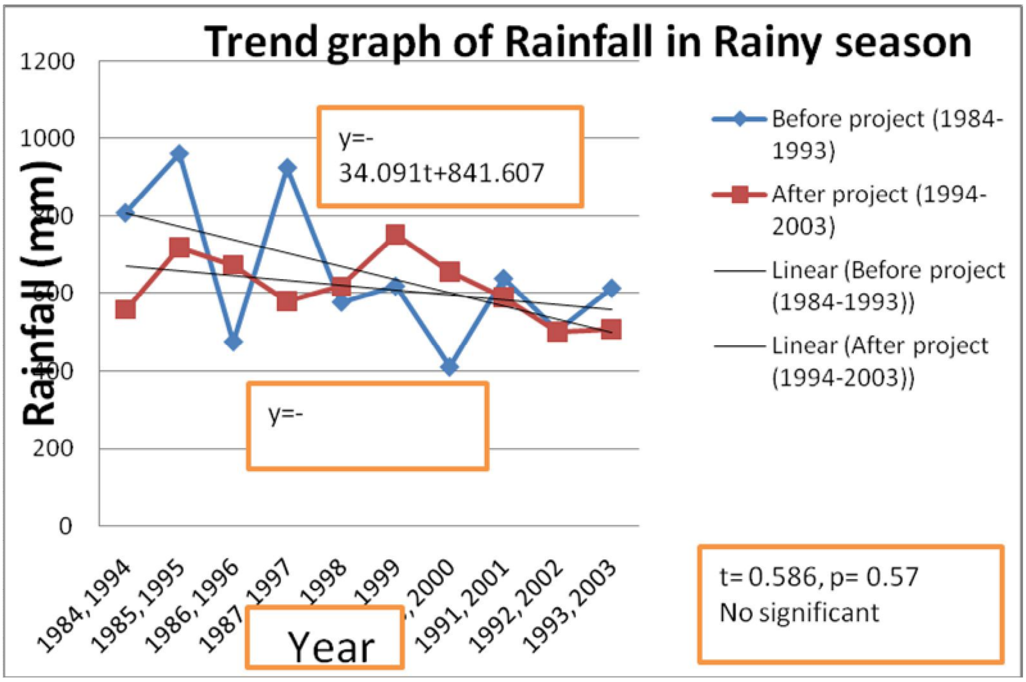

Figure 3.2: Trend in seasonal mean rainfall during rainy for before and after project

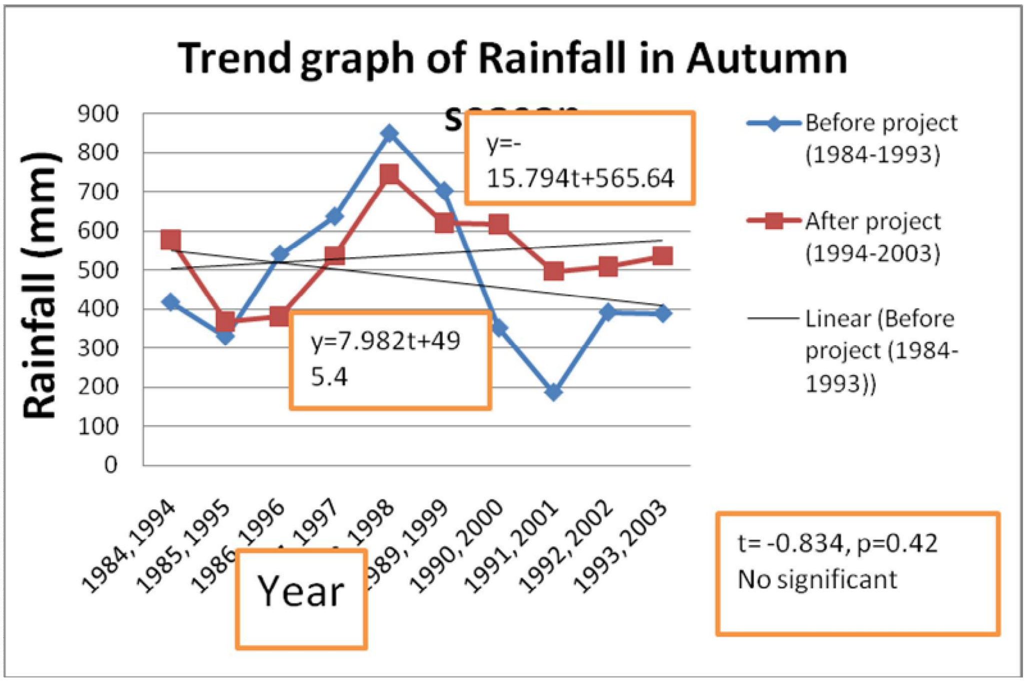

Figure 3.3: Trend in seasonal mean rainfall during autumn for before and after project

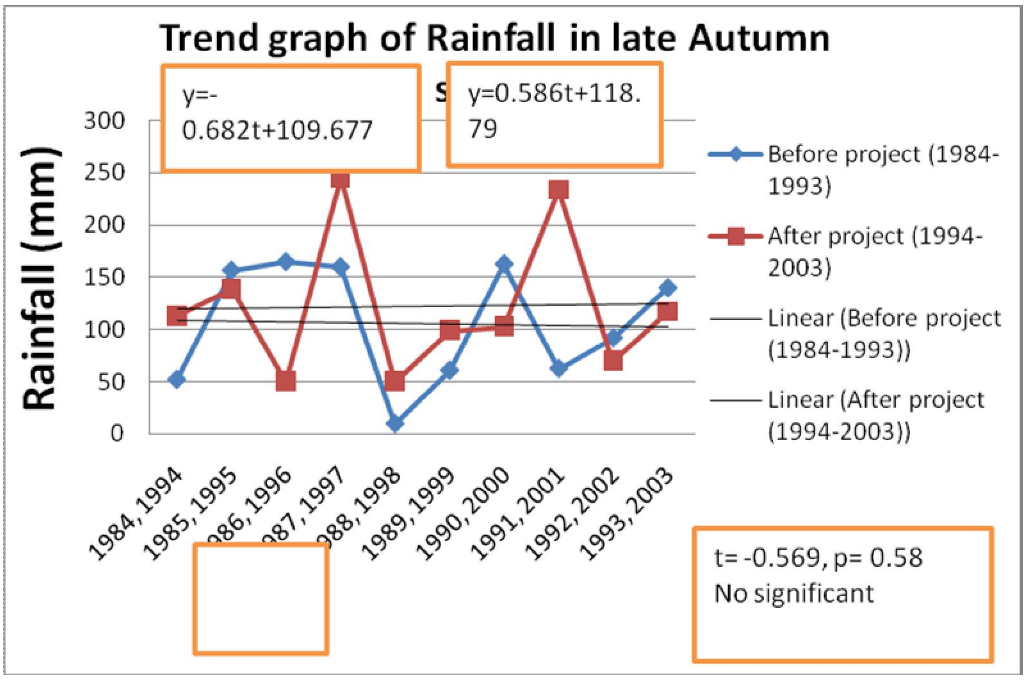

Figure 3.4: Trend in seasonal mean rainfall during late autumn for before and after project

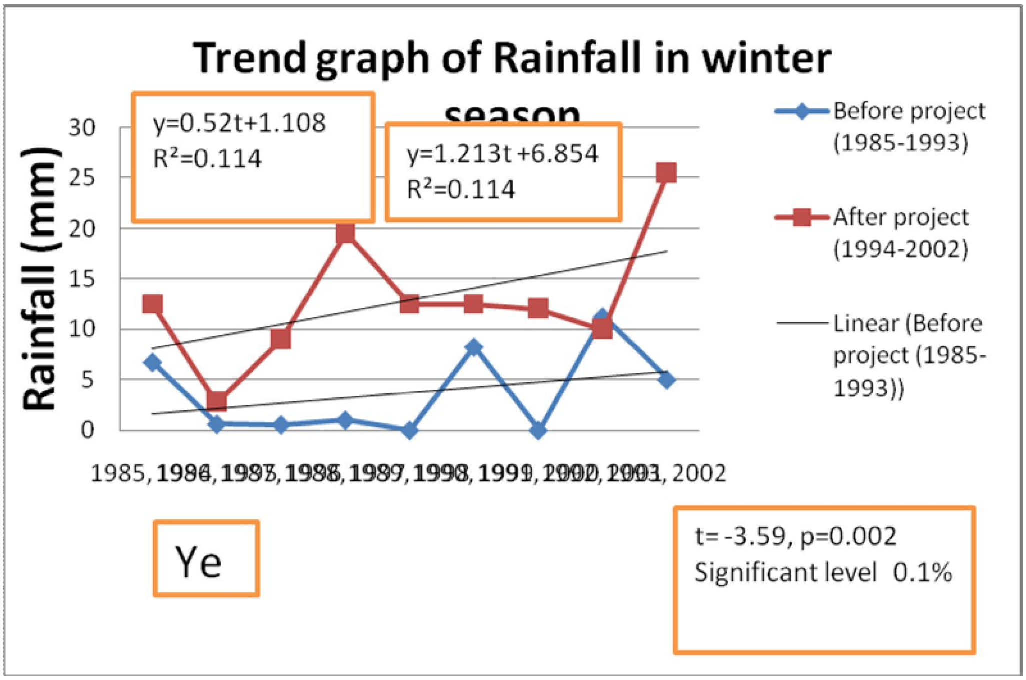

Figure 3.5: Trend in seasonal mean rainfall during winter for before and after project

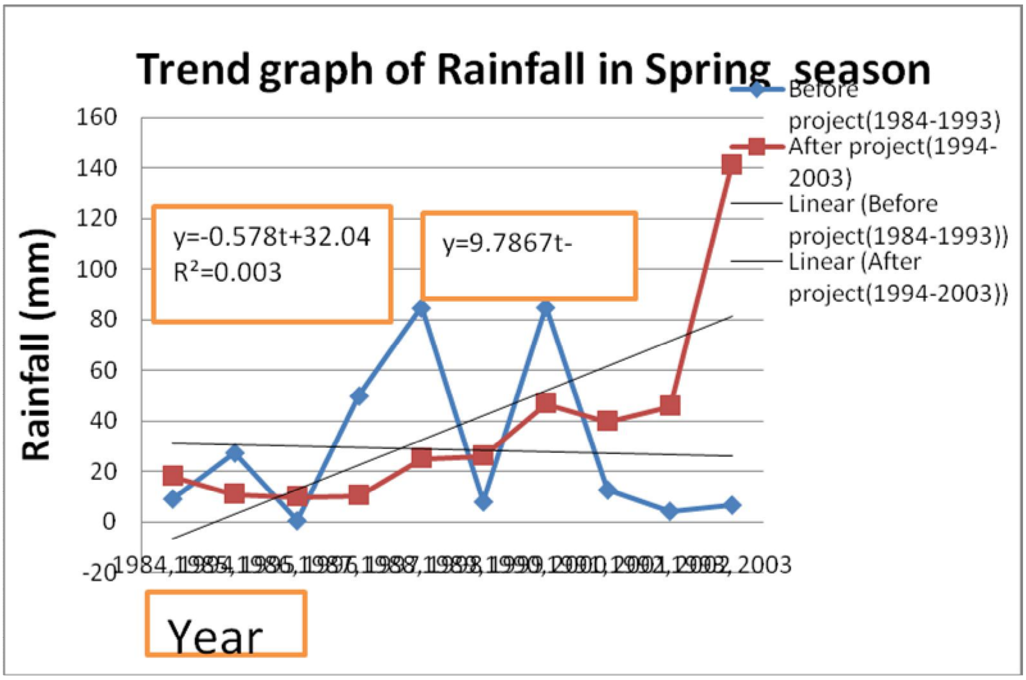

Figure 3.6: Trend in seasonal mean rainfall during spring for before and after project

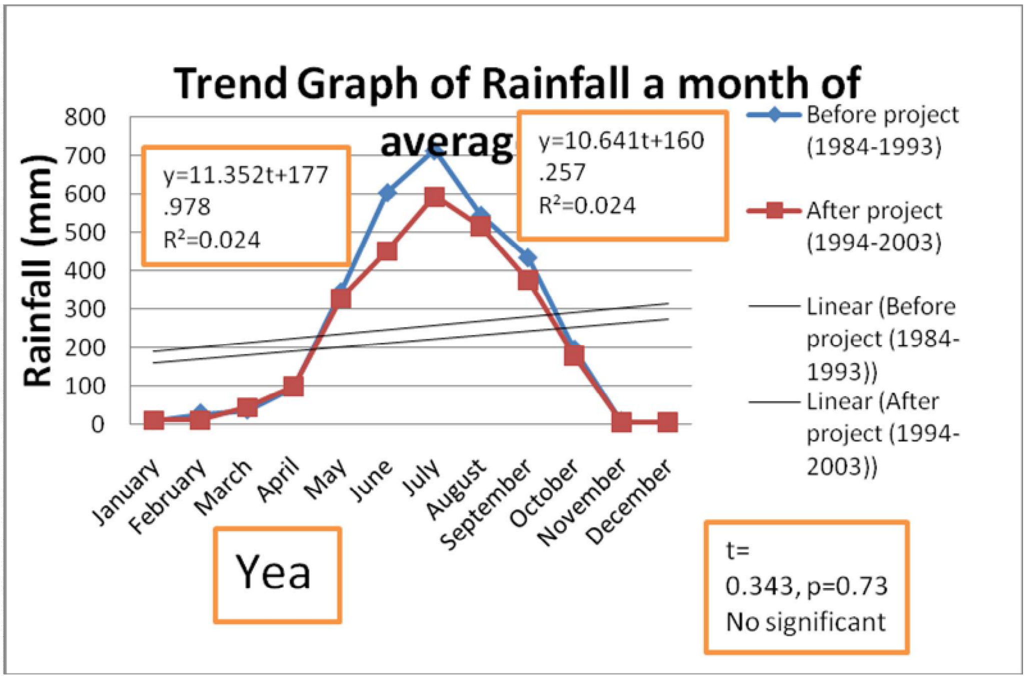

Figure 3.7: Trend in a Month of average years rainfall 12 Month

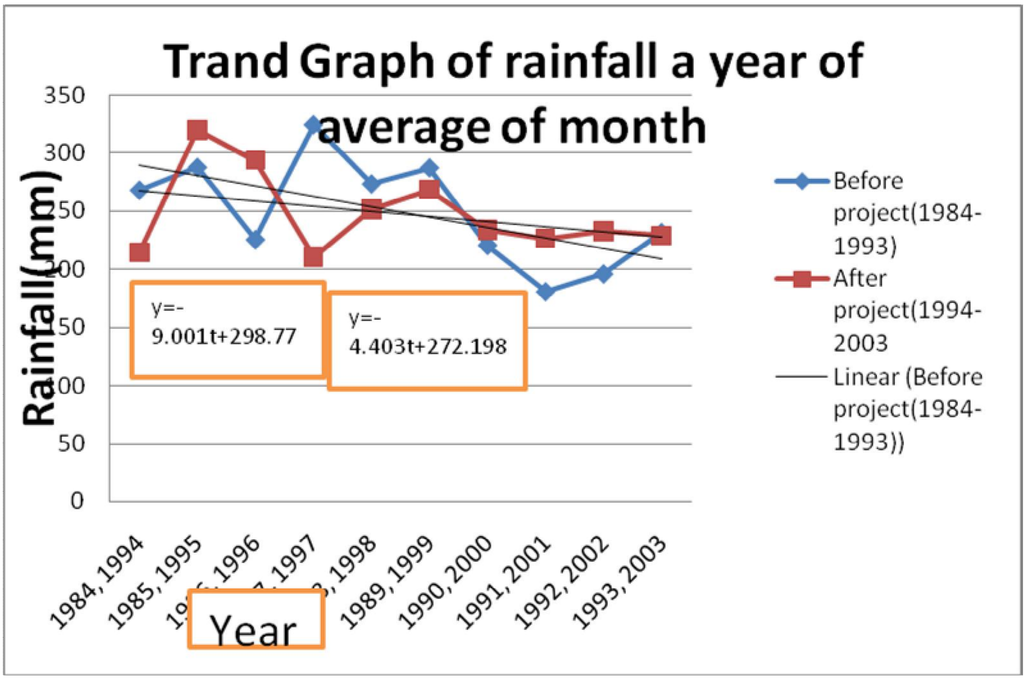

Figure 3.8: Trend a year of average month during 20 years(1984-2003)

Significant Analysis of Rainfall by t-test

Mean rainfall, and t-test for significant analysis for the two scenarios (before project and after project) in the Teesta Barrage Irrigation Project are shown in Table 3.1. and Table 3.2, respectively.

Table 3.1: Mean value of two periods for rainfall during six Bengali Seasons, a month of average years & a year of average months

Parameter	Seasons	Period	
		Before Project 1984-1993(1)μ_1	After Project 1994-2003(2)μ_2
	Summer	222	265
	Rainy	654	616
	Autumn	479	539
	Late autumn	106	122
	Winter	3.71	12.9
	Spring	28.9	37.6
	A month of average years	252	218
	A year of average month	249	248

Table 3.2: Results of t-test showing the mean difference between two periods of rainfall during six Bengali seasons, a month of average years & a year of average months.

Parameter	Seasons	Period	t-Statistic	P-value	Significance level (%)
Rainfall	Summer	(1984-1993)& (1994-2003)	-1.06	0.30	n.s
	Rainy	(1984-1993)& (1994-2003)	0.586	0.57	n.s
	Autumn	(1984-1993)& (1994-2003)	-0.834	0.42	n.s
	Late autumn	(1984-1993)& (1994-2003)	-0.569	0.58	n.s
	Winter	(1984-1993)& (1994-2003)	-3.59	.002	0.1
	Spring	(1984-1993)& (1994-2003)	-0.539	0.6	n.s
	A month of average years	(1984-1993)& (1994-2003)	0.343	0.73	n.s
	A year of average months	(1984-1993)& (1994-2003)	0.06	0.95	n.s

3.4.2 Discussion

Summer

It is seen from the Figure 1 and Table 3.1 that the mean rainfall of the post-project period (1994-2003) was increased from the mean rainfall of the pre-project period (1984-1993) during summer season. The mean difference of rainfall between the pairs (1984-1993) & (1984-2003) was not significant in this season (Table 3.2.).

Table 3.3: Estimated value of t-statistics for slope and p-value for different regression equations for rainfall in summer season

Data series	No. of obse:	Regression equation	T-Statistics for slope	P-Value	Remarks (change)
1984-1993	10	y= -4.418t +246.69	-9.31	0.000	(-)***
1994-2003	10	y= -4.757t+ 291.107	-7.92	0.000	(-)***

From above Table 3.3, it is found that the slope parameters of two equations for seasonal trend of rainfall during summer were statistically significant at 0.01% level and non zero with negative sign that show downward trend in terms of two periods. That means, rainfall was found to have decreasing trends with time change but the rate of decreasing of rainfall were 4.418 mm/month or 0.147mm/day in pre-project period and 4.75mm/month or 0.158mm/day in post-project period (1994-2003). Because the 2nd value of slope parameter is highest and 1st value of slope parameter is lowest. It proves that the rate of decreasing was more in period-2 and less in period-1.

Rainy season

It is seen from the Figure 2 and Table 3.1 that the mean rainfall of the period (1994-2003) after the Teesta Barrage Irrigation Project was increased from the mean rainfall of the period (1984-1993) before the teesta barrage irrigation project during rainy season. The mean difference rainfall (Table 3.2.) between the pair (1984-1993) & (1984-2003) was not significant.

Table 3.4: Estimated value of t-statistics for slope and p-value for different regression equations for rainfall in Rainy season

Data series	No. of obse:	Regression equation	T-Statistics for slope	P-Value	Remarks (change)
1984-1993	10	y=34.091t+841.607	-11.0	0.000	(-)***
1994-2003	10	y=12.444t+684.583	-22.8	0.000	(-)***

From above table 3.4 we can see that the slope parameters of two equations for seasonal trend of rainfall during rainy season were statistically significant at 0.01% level and non zero with negative sign that show downward trend in terms of two periods. That means, rainfall was found to have decreasing trends with time change but the rate of decreasing of rainfall were 34.091mm/month or 1.136mm/day and 12.444mm/month or 0.415mm/day for two periods, respectively. The value of slope parameter of equation -1 was maximum and the value of slope parameter of equation-2 was minimum. It proves that the rate of decreasing was more in period-1 and less in period-2. However, Karmakar and Khatun (1994) found that mean monthly rainfall increases from June to July at most places over Bangladesh.

Autumn

It is seen from the Figure 3 and Table 3.1 that the mean rainfall of the period (1994-2003) after the Teesta Barrage Irrigation Project was increased from the mean rainfall of the period (1984-1993) before the project during autumn season. The mean difference rainfall between the pair (1984-1993) & (1984-2003) was not significant (Table 3.2.).

Table 3.5: Estimated value of t-statistics for slope and p-value for different regression equations for rainfall in autumn season

Data series	No. of observation	Regression equation	T-Statistics for slope	P-Value	Remarks (change)
1984-1993	10	y=15.794t+565.64	-7.49	0.000	(-)***
1994-2003	10	y=7.982t+495.4	-15.0	0.000	(+)***

From above Table 3.5 it is found that the slope parameters of two equations for seasonal trend of rainfall during autumn season were statistically significant at 0.01% level and non zero with negative sign of equation -1 that show downward trend in 1st period and positive sign of equation-2 that show upward trend in 2nd period. That means, rainfall was found to have decreasing and increasing trends with time change but the rate of decreasing and increasing of rainfall was 15.794mm/month or 0.526mm/day in pre-project period and the rate of increasing was 7.982mm/month or 0.266mm/day in post-project period (1994-2003). The value of slope parameter of equation -1 was maximum and the value of slope parameter of equation-2 was minimum. It proves that the rate of decreasing was more in period-1 and less in the rate of increasing in period-2. Karmakar and Khatoon (1994) reported that mean monthly rainfall decreases during September in Bangladesh.

Late Autumn

It is seen from the Figure 4 and Table 3.1 that the mean rainfall of the period (1994-2003) after the Teesta Barrage Irrigation Project was increased from the mean rainfall of the pre-project period (1984-1993) during rainy season. The mean difference rainfall (Table 3.2.) between the pairs (1984-1993) & (1984-2003) was not significant.

Table 3.6: Estimated value of t-statistics for slope and p-value for different regression equations for rainfall in late autumn season

Data series	No. of observation	Regression equation	t-Statistics for slope	P-Value	Remarks (change)
1984-1993	10	y=0.682t+109.677	-5.52	0.000	(-)***
1994-2003	10	y=0.586t+118.79	-5.37	0.000	(+)***

From above table 3.6 we can see that the slope parameters of two equations for seasonal trend of rainfall during late autumn season were statistically significant at 0.01% level and non zero with negative sign of equation -1 that show downward trend in 1st period and positive sign of equation-2 that show upward trend in 2nd period. That means, rainfall was found to have decreasing and increasing trends with time change. But the rate of decreasing of rainfall was 0.682mm/month or 0.023mm/day in pre-project period and rate of increasing was 0.586mm/month or 0.020mm/day in post-project period (1994-2003). The value of slope parameter of equation -1 was maximum and the value of slope parameter of equation-2 was minimum. It proves that the rate of decreasing was less in period-1 and the rate of increasing of rainfall was more in period-2.

Winter

The mean rainfall Table 3.1 and Figure 5 of the period (1994-2003) after the Teesta Barrage Irrigation Project was increased from the mean rainfall of the period pre-project period (1984-1993) during winter season. The mean differences rainfall (Table 3.2) between the pairs of two periods (1984-1993) & (1984-2003) was statistically significant at 0.1% level.

Table 3.7: Estimated value of t-statistics for slope and p-value for different regression equations for rainfall in winter season

Data series	No. of obse:	Regression equation	t-Statistics for slope	P-Value	Remarks (change)
1984-1993	10	y=0.52t+1.108	0.77	0.45	n.s
1994-2003	10	y=1.213t+6.854	-3.4	0.004	(+)**

From above Table 3.7 it is seen that the slope parameter of equation-2 for seasonal trend of rainfall during winter season was statistically significant at 1% level and non zero with positive sign that show upward trend in terms 2nd period (1994-2003). That means, rainfall was found to have increasing trends with time change but the rate of increasing of rainfall were 0.52mm/month or0.017 mm/day and 1.213mm/month or 0.040mm/day for two periods, respectively. The value of slope parameter of equation -2 was maximum and the value of slope parameter of equation-1 was minimum. It proves that the rate of increasing of rainfall was more in period-2 and less in period-1. The rainfall trends of Bangladesh are increasing all over the country but most of the rainfall occurs in the monsoon period. So the uncertainty of rainfall is increasing from season to season. As a result agricultural activity of the country becomes victim to nature.

Spring

It is seen from the Figure 6 and Table 3.1 that the mean rainfall of the post-project period (1994-2003) of Teesta Barrage Irrigation Project was increased from the mean rainfall of the pre-project period (1984-1993) during spring season. The mean difference rainfall (Table 3.2.) between the pairs (1984-1993) & (1984-2003) was not significant.

Table 3.8: Estimated value of t-statistics for slope and p-value for different regression equations for rainfall in spring season

Data series	No. of obse:	Regression equation	t-Statistics for slope	P-Value	Remarks (change)
1984-1993	10	y=0.578t+32.04	-2.24	0.04	(-)*
1994-2003	10	y=9.787t-16.257	-2.58	0.02	(+)*

Table 3.8 reveals that the slope parameters of two equations for seasonal trend of rainfall during spring season were statistically significant at 5% level and non zero with negative sign of equation -1 that show downward trend in 1st period and positive sign of equation-2 that show upward trend in 2nd period. That means, rainfall was found to have decreasing and increasing trends with time change but the rate of decreasing rainfall was

0.578mm/month or 0.019mm/day in pre-project period and rate of increasing was 9.787mm/month or 0.326mm/day in post-project period (1994-2003). The value of slope parameter of equation -2 was maximum and the value of slope parameter of equation-1 was minimum. It proves that the rate of decreasing of rainfall was less in period-1 and rate of increasing of rainfall was more in period-2.

Rainfall in a Month of Average Years

It is seen from the Table 3.1 and Figure 7 that the mean rainfall of the period (1984-1993) before the Teesta Barrage Irrigation Project was increased from the mean rainfall of the period (1994-2003) after the project during a month of average years. The mean difference rainfall (Table 3.2) between the pairs (1984-1993) & (1984-2003) in a month of average years was not statistically significant

Table 3.9: Estimated value of t-statistics for slope and p-value for different regression equations for rainfall in a month of average years

Data series	No. of observation	Regression equation	t-Statistics for slope	P-Value	Remarks (change)
1984-1993	10	y=11.352t+177.978	-3.22	0.004	(+)**
1994-2003	10	y=10.267t+150.849	-3.29	0.003	(+)**

Table 3.9 reveals that the slope parameters of two equations for a month of average years trend of rainfall during a month of average years were statistically significant at 1% level and non zero with positive sign that show upward trend in both periods. That means, rainfall was found to have increasing trends with time change but the rate of increasing of rainfall was 11.352mm/month or 0.378mm/day for 1st period and 10.267mm/month or 0.342mm/day for 2nd period. The value of slope parameter of equation -1 was maximum and the value of slope parameter of equation-2 was minimum. It proves that the rate of increasing was more in period-1 and less in period-2 (1994-2003).

Rainfall in a Year of Average Months

It is seen from the Table 3.1 and Figure 8 that the mean rainfall of the period (1984-1993) before the Teesta Barrage Irrigation Project was small increased from the mean rainfall of the period (1994-2003) after the project during a month of average years. The mean difference rainfall (Table 3.2) between the pairs (1984-1993) & (1984-2003) in a year of average months was not statistically significant.

Table 3.10: Estimated value of t-statistics for slope and p-value for different regression equations for rainfall in a year of average months

Data series	No. of observation	Regression equation	t-Statistics for slope	P-Value	Remarks (change)
1984-1993	10	y=-9.009t+298.770	-16.9	0.000	(-)*
1994-2003	10	y=-4.403t+272.198	-21.5	0.000	(+)*

Table 3.10 reveals that the slope parameters of two equations for seasonal trend of rainfall during a year of average months were statistically significant at 0.01% level and non zero with negative sign that show downward trend of rainfall in 1st period. That means, rainfall was found to have decreasing trends with time change but the rate of decreasing of rainfall was 9.009mm/month or 0.300mm/day in period-1 and rate of increasing was 4.403mm/month or 0.147mm/day in post-project period (1994-2003). The value of slope parameter of equation -1 was maximum and the value of slope parameter of equation-2 was minimum. It proves that the rate of decreasing of rainfall was more in period-1 and rate of increasing of rainfall was less in period-2.

3.5 Conclusion

From this study, it is found that mean rainfall in post-project period (1994-2003) of Teesta Barrage Irrigation Project was increased in all six seasons in the study area compare to mean rainfall of pre-project period (1984-1993). However, the mean difference rainfall between the periods (1984-1993) & (1984-2003) was found significant only in winter season. Therefore, it is concluded that Teesta Barrage Irrigation Project has positive impacts on rainfall pattern in the project area.

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Chapter 4
Effect of Teesta Barrage Irrigation Project on Agriculture, Fisheries, Drinking Water and Disease Incidence

4.1 Introduction

Development interventions should be the broad programmes of sectoral change in proportion and measures at structural level and constitutes of the environmental states by the activities of the government and community (Goodhand, 2001). This is not the case in Bangladesh. In Bangladesh, development interventions mainly include efforts of government through various departments. The development interventions in rural areas of Bangladesh started in the 1960s with the introduction of HYV paddy cultivation, levee & embankment construction for flood protection and rural road construction (Ahsan, 2006). It is assumed that major environmental degradation in rural areas is mainly taking place due to excessive use of agrochemicals in crops and unplanned construction of road and embankments. The impacts of flood control, drainage and irrigation projects are the breaking up of the link between the beels and the rivers through the canals. As consequence, per capita availability of fish has declined over the years causing serious nutritional and other problems (PC, 1990). Whereas, Bashar (2004) explicitly states that the standard of living for rural people depends on agriculture commodities. In Bangladesh excessive cultivation and the absence of proper crop rotation practice are the primary reasons behind agricultural land degradation (Anonymous, 2001).

Introduction of irrigation facilities assured more production of crops in the dry season through supplemental irrigation of the rain fed crops, ensured greater productivity and created employment opportunities in the crop sectors. With a view to increase agriculture production through supplementary gravity irrigation with flood protection & drainages facilities, the Teesta Barrage Irrigation Project was implemented. This chapter provides information of the impact of Teesta Barrage Irrigation Project (TBIP) on agriculture, fisheries, livestock, poultry, social forestry, drinking water availability and disease incidence in the command area of TBIP under three upazillas of Jaldhaka, Dimla and Kishoreganj of Nilphamari district.

4.2 Objective of the study

To study the impact of Teesta Barrage Irrigation Project (TBIP) on agriculture, fisheries, social forestry, drinking water and disease incidence in the command area of TBIP.

4.3 Data collection and analysis

4.3.1 Data Collection

The study is based on both primary and secondary data. Secondary data was collected from Teesta Barrage Monitoring Office, Dalia Lalmonirhat, Ministry of Agriculture and Bangladesh Bureau of Statics (BBS).

Primary data was collected through field survey in three upazillas of Dimla, Jhaldhaka and Kishorgonj. A structured questionnaire was prepared for data collection on agriculture, fisheries, social forestry, drinking water sources, and disease incidence. A random questionnaire survey was done on 120 respondents, 40 nos. in each upazila during this study (Questionnaire Appendix)

4.3.2 Sample size and sampling procedure

Sampling method plays a vital role in research work. Sampling prepares sufficient information about people. It plays role to select a part of the population that exhibit all of the characteristics of the population. When we come to a decision about a people as possible. From 3 thena/Upazila's we selected 3 thana/Upazila's with random sampling. Selected each on thena/Upazial from 3 thana/Upazila's which has at least six words/Unions. then selected one vilage/Moholla from 3 thana/Upazila's which has at least six vilage/Mohollas. Then we get, Total sample size 44 villages/Mohollas and total sample size of households for the study area is 120.

There are 6 Upazilas and 6 Thanas in Nilphamari District. Sample area has selected according to Table-4.0. Sample size has taken from 3 Upazilas of total households, (10,971) by same method bellow.

Table: 4.0: Sample size areas, corresponding wards/union parishads and households number Source: Based on BBS census-2001. Prepared by researcher

Sl No	Name of the area	Name of Wards/Union Parishads	Number of parts Moholla/Village	Total Households (Ni)	Sample size
01	Dimla	Khalisha Chapani	02 (parts)	274	3
02	"	Jhunagach Chapni	01 (parts)	275	3
03	"	Nawtra	07 (parts)	1555	17
04	"	Goya Bari	06 (parts)	1554	17
05	Jaldhaka	Balagram	02 (parts)	1280	14
06	"	Goalmonda	03 (parts)	1188	13
07	"	Khutamara	05 (parts)	1005	11
08	"	Goalna	02 (parts)	183	2
09	Kishorgonj	Barovita	06 (parts)	2285	25
10	"	Ranachandi	09 (parts)	914	10
11	"	Putimari	01 (parts)	457	5
			Total = 44	10,971	120

Due to time and budget constraint it was not possible to cover 10971 households (Table-4.0). For this reason Yamane's mathematical formula was used for resolving the sample size.

Taro Yamanes's (1970) formula : $n = \frac{N}{1+Ne^2}$

Where, N = total household, 10,971 n = sample size and e = level of confidence, 0.091

Therefore the sample size, $n = \frac{10971}{1+10971\times(0.091)^2}$

$n = 119.44$

$n = 120$

Then a stratum with proportion allocation formula was used to divide the sample Number proportionately in each of the eleven Strata.

Here, $n_i \alpha N_i$

or, n_i = K N_i

or, $n_i = \frac{n}{N} \times N_i$ Where, K = $\frac{n}{N}$

Where, i = 1,2,3,4,5;7,8,9,10,11 ; N = Total household, n = Sample size

Therefore, n_1 = 3, n_2 = 3, n_3 = 17, n_4 = 17, n_5 = 14, n_6 = 13, n_7 = 11, n_8 = 2, n_9 = 25, n_{10} = 10, n_{11} = 5

Now we get, From Formula, n = $\sum n_i$

$= n_1 + n_2 + n_3 + n_4 + n_5 + n_6 + n_7 + n_8 + n_9 + n_{10} + n_{11}$

= 3+3+17+17+14+13+11+2+25+10+5

= 120

4.3.3 Methods of date processing and analysis

As the proposed study is descriptive and qualitative in nature, both qualitative and quantitative data have been collected from primary and secondary sources. Both types of date have been collected through planned questionnaires, participant observation, face- to-face in-depth interview, and document analysis. The information received from other trustworthy sources has been recognized properly. The date collected from the field have been analyzed both quantitatively and qualitatively. Microsoft Excel were used for date processing and statistical analysis. The quantitative date have been put into table, and bar diagrams and pie charts have been used to make the results clear. The date collected from different sources have been analyzed independently and the researcher has made his comments at the later part of the thesis.

4.3.4 Data Analysis

Data was tabulated first in computer and then analyzed by Microsoft Excel program.

4.3.5 Results and Discussion

Impact on Agriculture

The cropping pattern in the study area is shown in Table 4.1.and Figures 4.1-4.6 (Appendix) In pre-project scenario, wheat, tobacco and potato are the main rabi crops in all three upazillas of Dimla, Jaldhaka and Kishorgonj in the command area of Teesta Barrage Irrigation Project. However, in post-project period, tobacco cultivation is reduced and HYV-Boro cultivation is increased.

Table 4.1 Change of area of cropping pattern level before and after project in (Bigha)

Dimla (n=40)				Jaldhaka (n=40)		Kishorgonj (n=40)	
Crop Seasons	**Name of crops**	**Before project**	**After project**	**Before project**	**After project**	**Before project**	**After project**
Rabi	HYV Boro	0.25	11.025	1.50	9.30	1.25	8.90
	Wheat	1.50	0.00	1.65	0.25	1.05	0.00
	Corn/Maize	0.00	0.50	0.00	0.15	0.00	1.15
	Mustard	0.30	0.50	0.01	0.00	0.20	0.00
	Pulses	0.05	0.00	0.01	0.00	0.80	0.00
	Potato	0.663	1.275	0.75	0.20	1.45	5.00
	Tobacco	0.825	0.10	2.20	0.00	3.55	0.575
Kharif	Jut	2.975	0.08	3.95	0.00	3.80	0.15
	Aus	4.70	0.00	1.85	0.00	4.500	0.00
	Broadcast aman	0.05	0.00	0.10	0.00	0.01	0.00
	Transplanted Aman	11.05	11.55	9.45	9.55	11.35	11.35
	sugarcane	0.00	0.00	0.00	0.00	0.00	0.00
	Turmeric	0.05	0.05	0.001	0.001	0.00	0.00
	Zinger	0.013	0.13	0.01	0.01	0.00	0.00

In kharif season, aus rice was the predominant crop in pre-project period but after implementation of Teesta Barrage Irrigation Project T-aman occupied the places of aus and jute. The main aim of Teesta Barrage Irrigation Project was to create irrigation facilities for T-aman during kharif period. Farmers in the study area are enjoying the full benefit of Teesta project and resulting T-aman cultivation is increased manifold. Jute is still cultivated in small areas but aus is totally extinct from the study area (Table 4.1).

Impact on Open Water and Culture Fisheries

Bangladesh is rich in fish and aquatic resources. Bangladesh's inland/open water bodies are known to be the habitat of 266 species of indigenous fish (Ali, 2001). Before the Teesta Barrage Irrigation Project, the command was rich in open water fish species. Buri Teesta, different beels and khals were used as the spawning and living ground for many open water fish species. These capture fishes met the protein demand of local people. But after construction of Teesta Barrage Irrigation Project, the spawning grounds of open water fisheries were lost. In before project scenario, people can catch 125.5 – 159.50 kg of open water fish per year but after implementation of Teesta Project it reduced to 24.25-34.30 kg per year (Table 4.2). and Figures 4.7-4.9 (Appendix) The impacts of flood control, drainage and irrigation projects are the breaking up of the link between the beels and the rivers through the canals. Thus fish output is lost because fishing grounds are converted to paddy fields (Ali, 2001).

On the other hand, pond area for culture fisheries is not increased much due to sandy soil condition which is not favorable for water retention in pond.

Table 4.2: Open water and culture Fisheries in project area

Dimla (n=40)			Jaldhaka (n=40)		Kishorgonj (n=40)	
	Before project	**After project**	**Before project**	**After project**	**Before project**	**After project**
Open water Fish catch Kg	125.5	34.30	159.50	24.25	131	25
Pond Area (bigha)	0.70	0.79	0.81	0.89	0.41	0.63

It is evident that ponds within the project area are now free from seasonal flooding and water logging which has enhanced the aquaculture opportunity in different ponds lakes, canals, low lying depressions and paddy lands. The main canal (33.78 km) and major secondary canals (74.43km) can be provided with water resources promoting culture based fisheries. A mixed response on fish culture was found during field survey. About 47% respondents reported about the increase of fish culture whereas same percent opined negative response on fish culture and no change is supported by 6% respondents (Table 4.3) and Figures 4.10-4.12 (Appendix)

Table 4.3: Respondents' opinion regarding increased fish culture before and after Teesta Barrage Irrigation project in (%)

Opinion: Increased fish culture	Name of Upazilla			All Upazilla (n=120)
	Dimla (n=40)	Jaldhaka (n=40)	Kishorgonj (n=40)	
Yes	40	50	50	47
No	50	40	50	47
Same	10	10	0.00	6
Total	100	100	100	100

Impact on Drinking Water

Teesta Barrage Irrigation Project is found to change the drinking water use pattern in the project area. In pre-project period, local peoples were used to drink water from dug-well but after the implementation of Teesta Project peoples are mainly drinking water from tube-well (Table 4.2 and Figures 4.13-4.15 in Appendix).

Table 4.4: Impact of Teesta Barrage Irrigation project on Drinking water sources: In %

Dimla (n=40)			Jaldhaka (n=40)		Kishorgonj (n=40)	
Name of Well	Before project	After project	Before project	After project	Before project	After project
Dug-well	90	0.00	55	0.00	55	0.00
Tub-well	10	100	45	100	45	100
Shallow-tubewell	0.00	0.00	0.00	0.00	0.00	0.00
River	0.00	0.00	0.00	0.00	0.00	0.00
Pond	0.00	0.00	0.00	0.00	0.00	0.00

Impact on Human Disease Incidence

For changing of drinking water sources from dug-well to tube-well, the incidence of water-borne diseases (diarrhea, dysentery and typhoid) are found to decrease in the Teesta project area in all three upazilas of Dimla, Jaldhaka and Kishorgonj (Table 4.3 and Figures 4.16-4.18 in Appendix). In Kishorganj upazila, out 40 respondents, most of them expressed that they were suffering from diarrhea, dysentery and typhoid in pre-project period but after the implementation of Teesta Barrage Irrigation Project this scenario is improved for flood free condition and availability of pure drinking water from tube-well.

Table 4.5: Impact of Teesta Barrage Irrigation project on Human disease incidence (%)

Dimla (n=40)			Jaldhaka (n=40)		Kishorgonj (n=40)	
Name of Diseases	**Before project**	**After project**	**Before project**	**After project**	**Before project**	**After project**
Diarrhea	80	70	90	70	100	85
Dysentery	90	80	61	60	100	95
Typhoid	60	35	75	40	90	65
Fever	100	95	60	65	95	95
Cough	95	100	60	65	95	90
Skin disease	9	0.0	8	0.0	3.0	0.0

Impact on Livestock Disease Incidence

Teesta Barrage Irrigation Project has both positive and negative impacts on livestock disease incidence. The incidence of foot and mouth, and wooden tongue diseases are decreased whereas the diseases like ringworm, lumpy jaw and anthrax are increased after Teesta Project (Table 4.4 and Figures 4.19-4.21 in Appendix).

Table 4.6: Impact of Teesta Barrage Irrigation project on Livestock disease incidence (%) in Study Area

Dimla (n=40)			Jaldhaka (n=40)		Kishorgonj (n=40)	
Name of Disease	**Before project**	**After project**	**Before project**	**After project**	**Before project**	**After project**
Foot and mouth Disease	100	80	100	75	100	85
Wooden tongue	70	30	60	52	57	62
Ringworm	10	50	7	45	11	29
Lumpy jaw	0	2	0	5	0	1
Foot rot	5	4	5	2	6	7
Anthrax	0	30	0	45	0	47

Impact on Fruiting Plants Plantation

Before the Teesta Barrage Irrigation Project, the vegetation in the study area is damaged by floods particularly the fruit plants like papaya, banana and jackfruit which are very vulnerable to flood water. Besides the irrigation facilities, Teesta Barrage Irrigation Project has also created flood free condition in the command area of this project. Therefore, fruiting plants plantation like mango, jackfruit, guava, coconut, litchi, etc. is increased nearby the homesteads and roads after the Teesta Barrage Irrigation Project (Table 4.5 and Figures 4.22-4.24 in Appendix).

Table 4.7: Impact of Teesta Barrage Irrigation project on fruiting plants

Dimla (n=40)			Jaldhaka (n=40)		Kishorgonj (n=40)	
Name of fruiting plants	**Before project**	**After project**	**Before project**	**After project**	**Before project**	**After project**
Mango	5.75	7.80	5.35	12.70	7.20	16.40
Jackfruit	4.10	3.30	3.10	6.55	1.95	3.55
Guava	1.80	2.00	0.80	2.55	1.45	3.60
Litchi	0.20	0.55	0.05	1.65	0.00	0.35
Coconut	1.00	3.15	0.90	1.35	0.30	0.65
Black-berry	0.20	0.60	0.55	1.15	0.35	0.90
Plum	0.55	0.60	0.20	0.55	0.35	0.95
Betel nut	59.90	70.80	16.60	50.8	4.85	19.00

Impact on Social Forestry

There is no natural forest in the study area. The planted plants on the highlands around the roads, embankments and homesteads serve as the social forest. Forest and homestead vegetation play an important role in environmental balance and economic life of the people of Bangladesh in terms of food and nutrition, construction materials, biomass fuel, fodder, shelter and shade, windbreaks, organic matter, erosion control and balance between flood and drought. About 5 species of plants are used for social forestry at homesteads, roads and embankment sides. In pre-project period, shishu was the only one social forest plant in the study area but after the implementation of Teesta Barrage Irrigation Project, social forestry is diversified with species like eucalyptus, mahogany, akashmoni and babla (Table 4.6 and Figures 4.25-4.27 in Appendix).

Table 4.8: Impact of Teesta Barrage Irrigation project on social plants (nos./household)

Dimla (n=40)			Jaldhaka (n=40)		Kishorgonj (n=40)	
Name of social plants	**Before project**	**After project**	**Before project**	**After project**	**Before project**	**After project**
Eucalyptus	0.00	67.60	0.00	59.7	0.00	30.8
Mahogany	0.00	9.90	0.00	7.70	0.00	7.90
Shishu	0.60	1.25	0.00	2.35	0.00	0.40
Akashmoni	0.00	1.55	0.00	0.00	0.00	0.00
Babla	0.00	0.00	0.00	0.00	0.00	0.00

Respondents' Opinion on Different Facilities after the Teesta Barrage Irrigation Project

All of the respondents opined that Teesta Barrage Irrigation Project has played important role in flood protection, food production and communication as well as it improved the business opportunity and standard of life of local people in the project area (Table 4.7).

Table: 4.9: Respondents' opinion regarding different facilities after Teesta Barrage Irrigation project: In %

Different Facilities	Respondent Opinion	Name of Upazilla			All Upazilla n-120
		Dimla (n=40)	Jaldhaka (n=40)	Kishorgonj (n=40)	
Improved Irrigation	Yes	100	100	100	100
	No	0	0	0	0
Increased agricultural production	Yes	100	100	100	100
	No	0	0	0	0
Flood Protection	Yes	100	100	100	100
	No	0	0	0	0
Improved road communication	Yes	100	100	100	100
	No	0	0	0	0
Increased poultry farms	Yes	100	100	100	100
	No	0	0	0	0
Increased business opportunity	Yes	60	55	50	55
	No	25	25	30	27
Increased income	Yes	100	100	100	100
	No	0	0	0	0
Improved life standard	Yes	100	100	100	100
	No	0	0	0	0

4.4 Conclusion

From this study it is found that Tessta Barrage Irrigation Project has incasesed the HYV-Boro cultivation, culture fisheries and social forestry. The Project also improved road communication as well as standard of life of people in the project area.

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Appendix Chapter 4

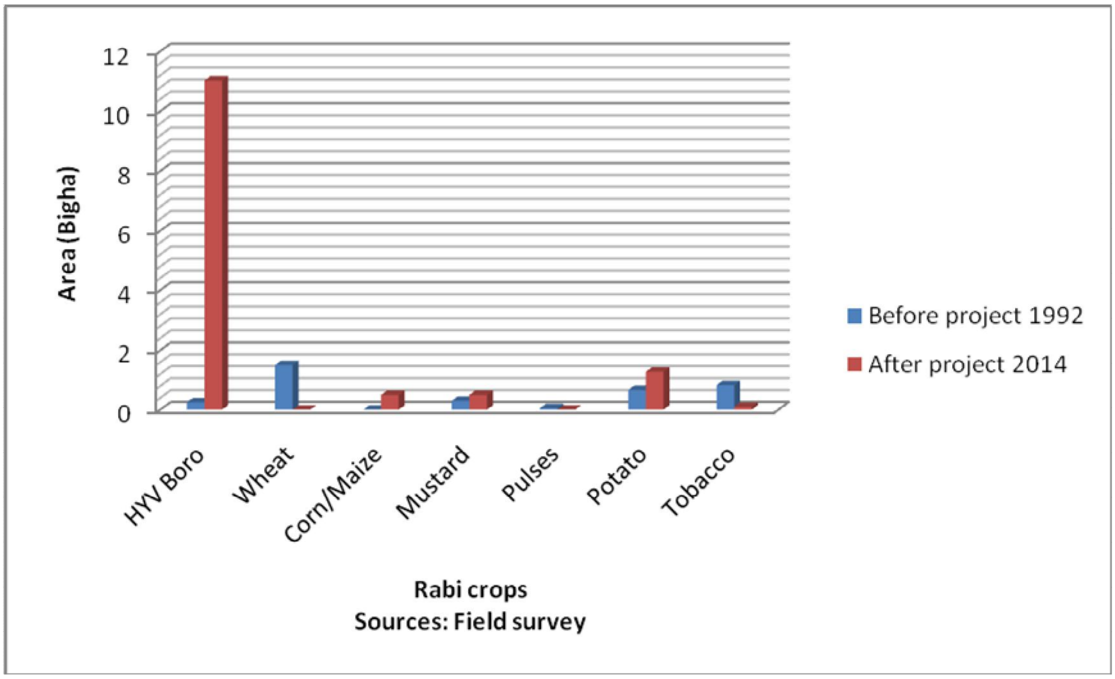

Figure 4.1 Changing of Rabi Crops pattern in project area (Dimla Upzilla)

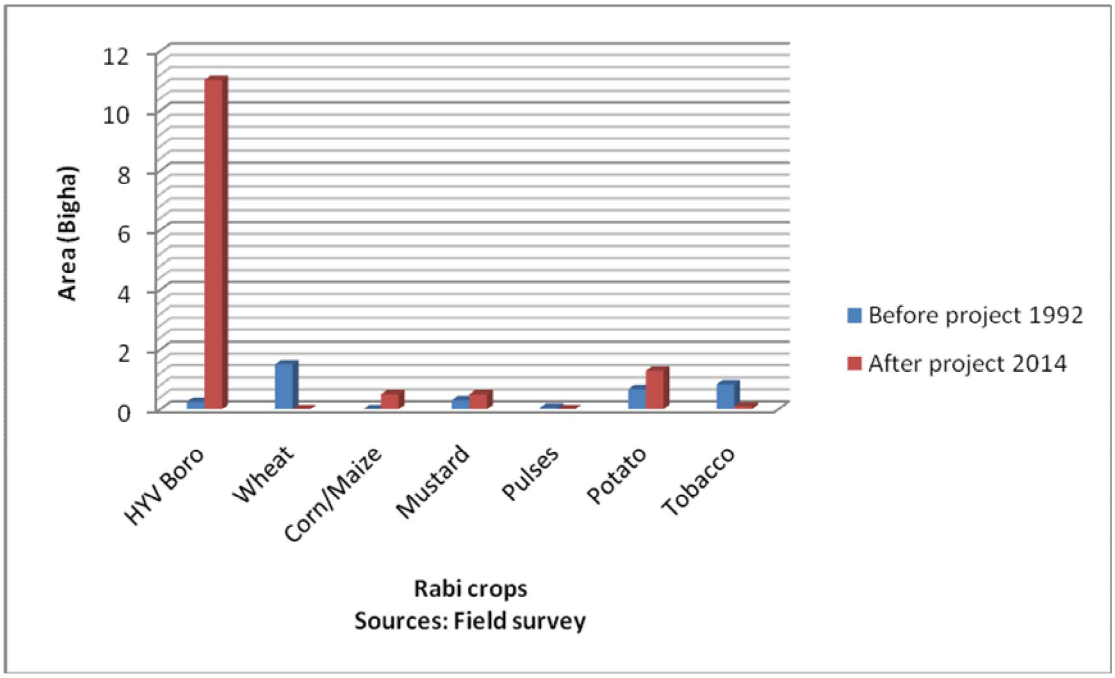

Figure 4.2 Changing of Rabi Crops pattern in project area (Jaldhaka Upzilla)

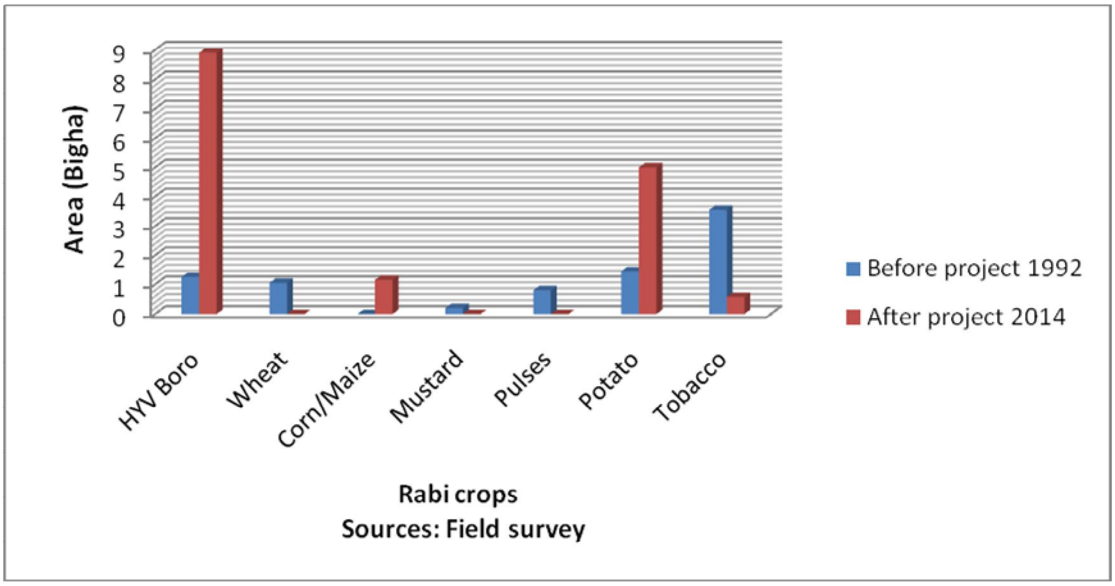

Figure 4.3 Changing of Rabi Crops pattern in project area (Kishorgonj Upzilla)

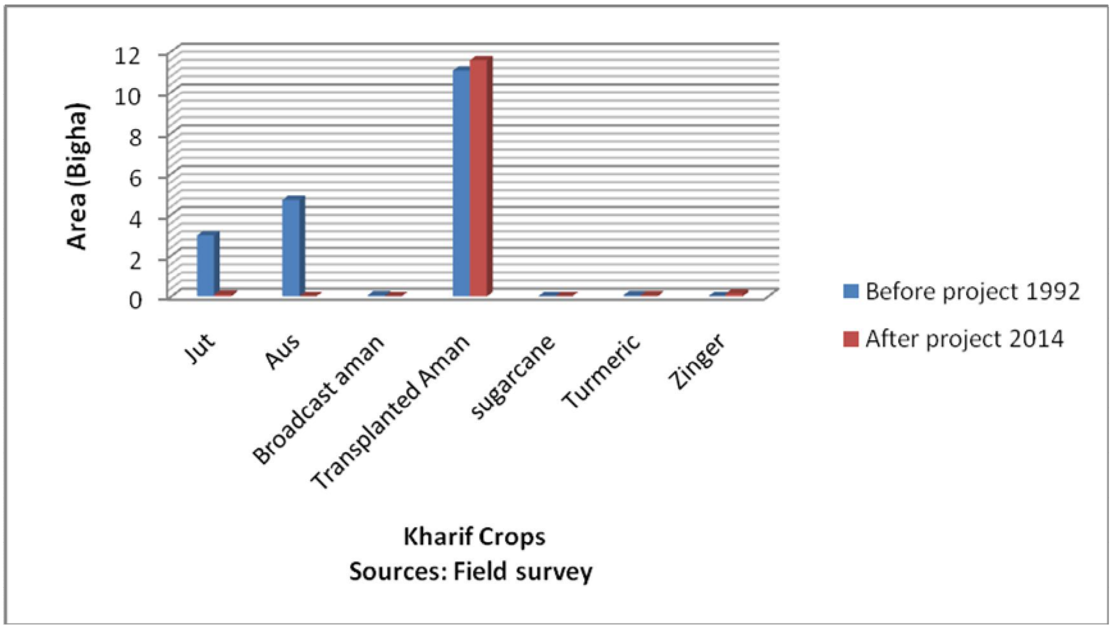

Figure 4.4 Changing of kharif Crops pattern in project area (Dimla Upzilla)

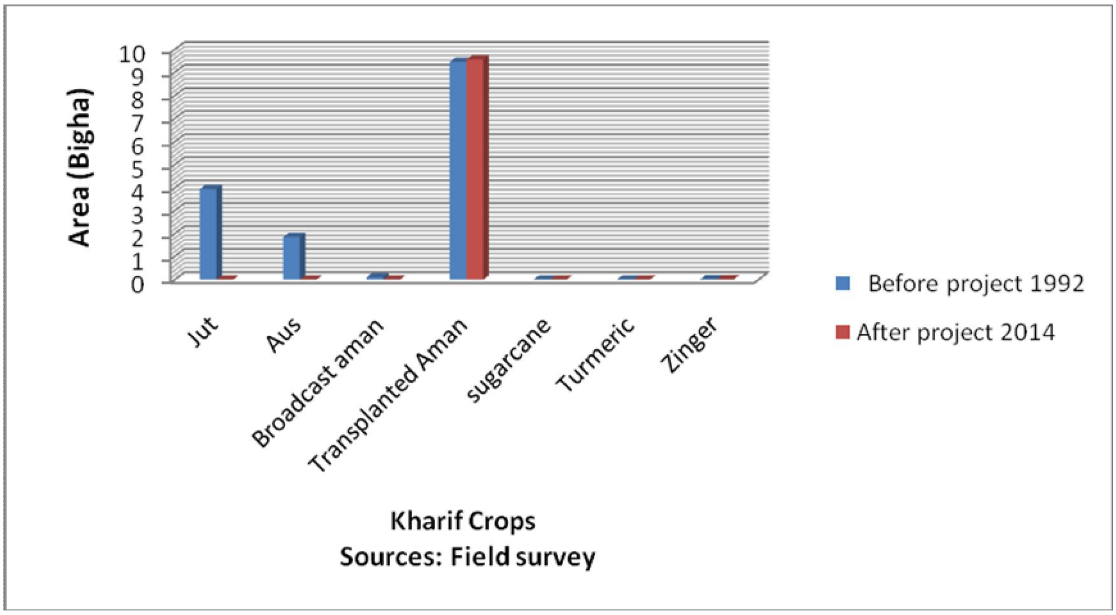

Figure 4.5 Changing of kharif Crops pattern in project area (Jaldhaka Upzilla)

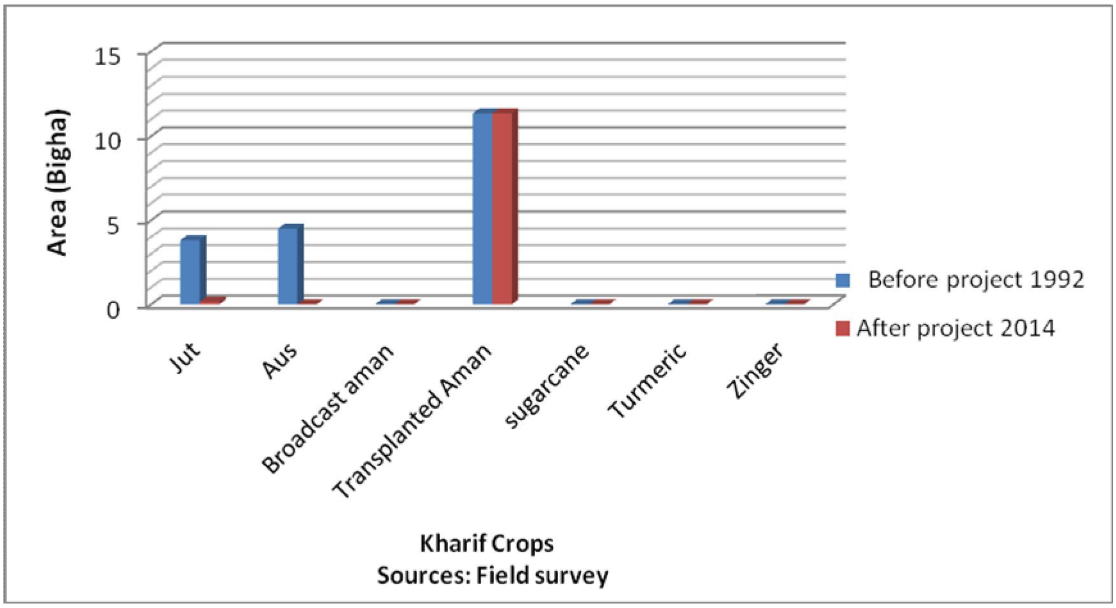

Figure 4.6 Changing of kharif Crops pattern in project area (Kishorgonj Upzilla)

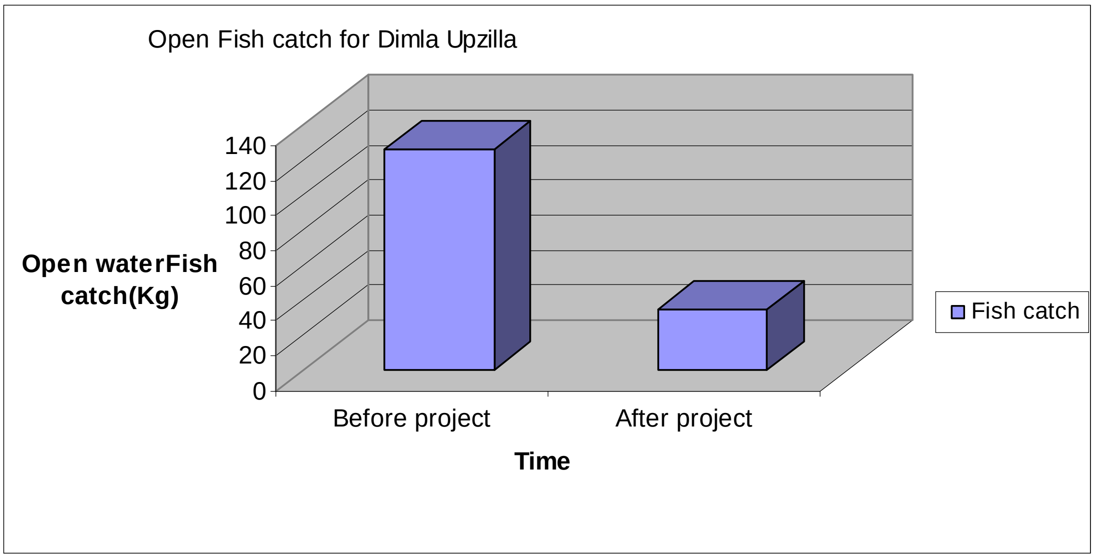

Figure 4.7: Open fish catch (kg) before after and project Dimla Upazilla

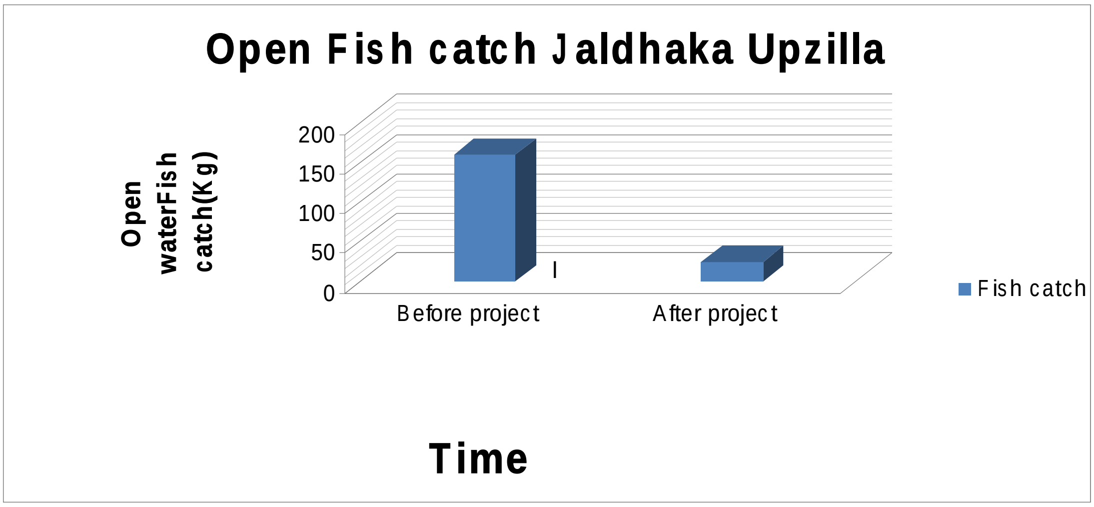

Figure 4.8: Open fish catch (kg) before after and project Jaldhaka Upazilla

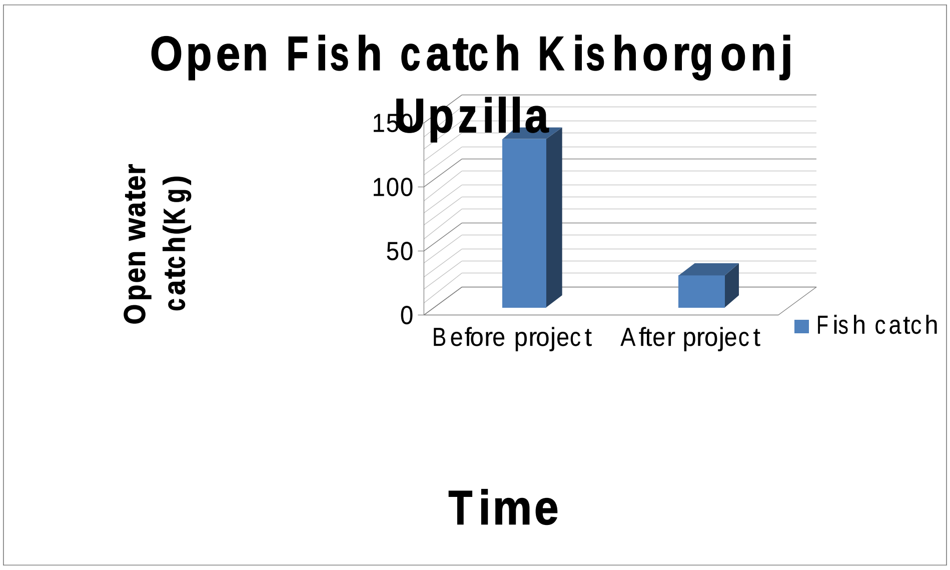

Figure 4.9 : Open fish catch (kg) before after and project Kishorgonj Upazilla

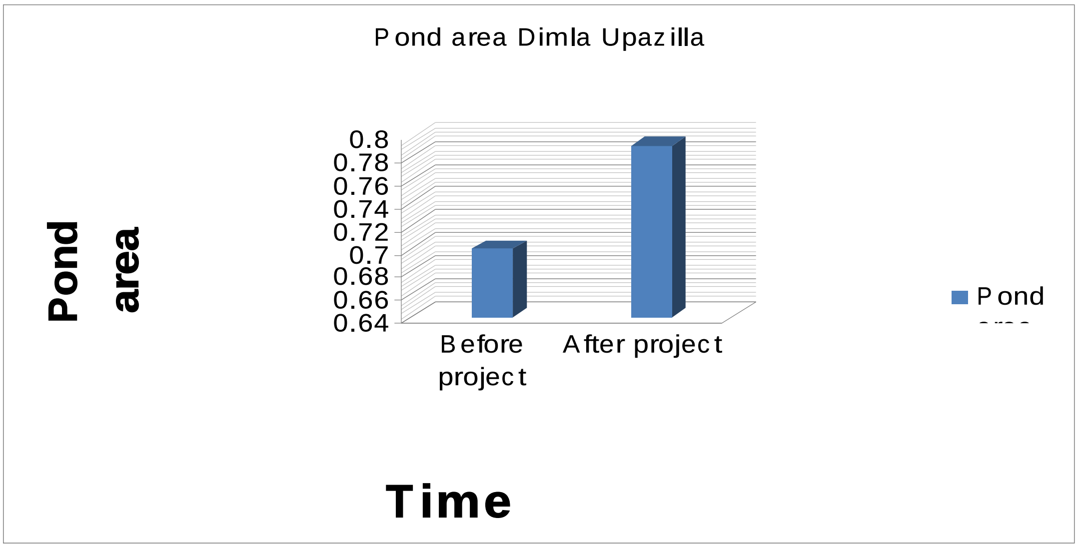

Figure 4.10: Pond Area Dimla Upazilla before after and project

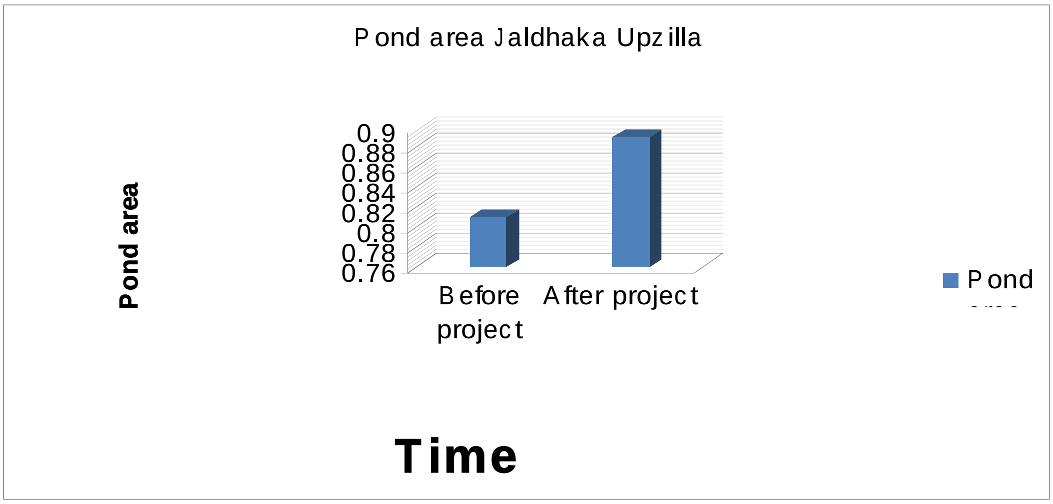

Figure 4.11: Pond Area Jaldhaka Upazilla before after and project

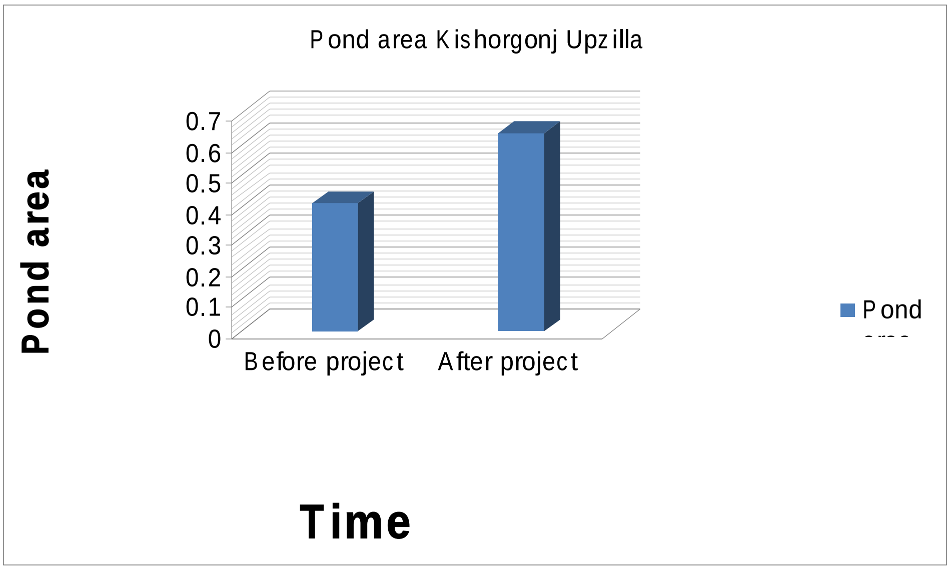

Figure 4.12: Pond Area Kishorgonj Upazilla before after and project

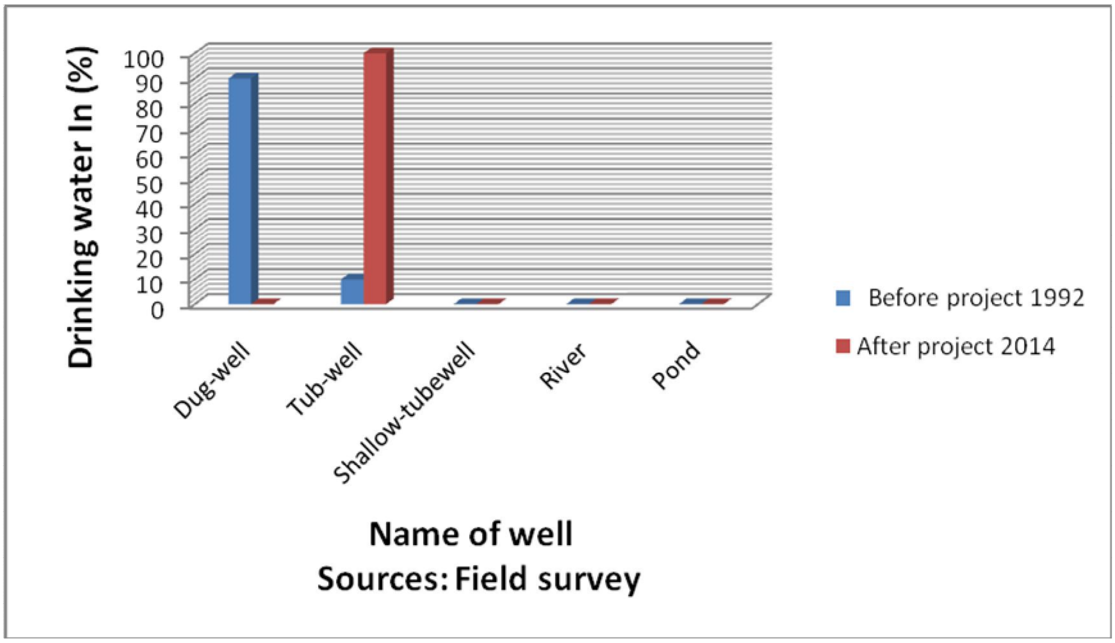

Figure 4.13: Changing of Drinking water pattern in project area (Dimla Upzilla)

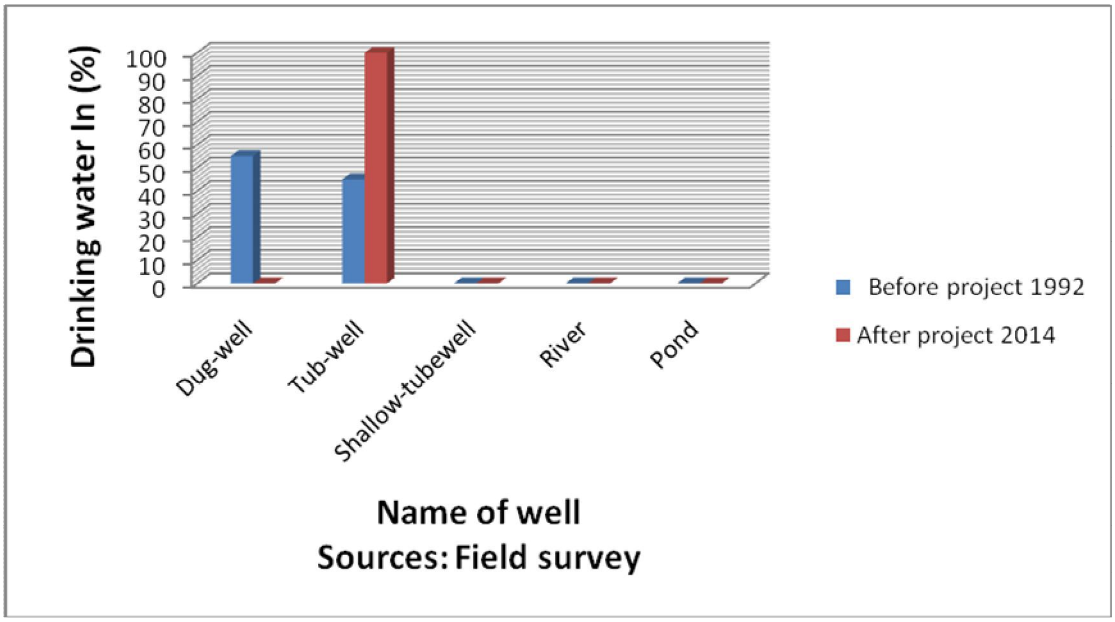

Figure 4.14: Changing of Drinking water pattern in project area (Jaldhaka Upzilla)

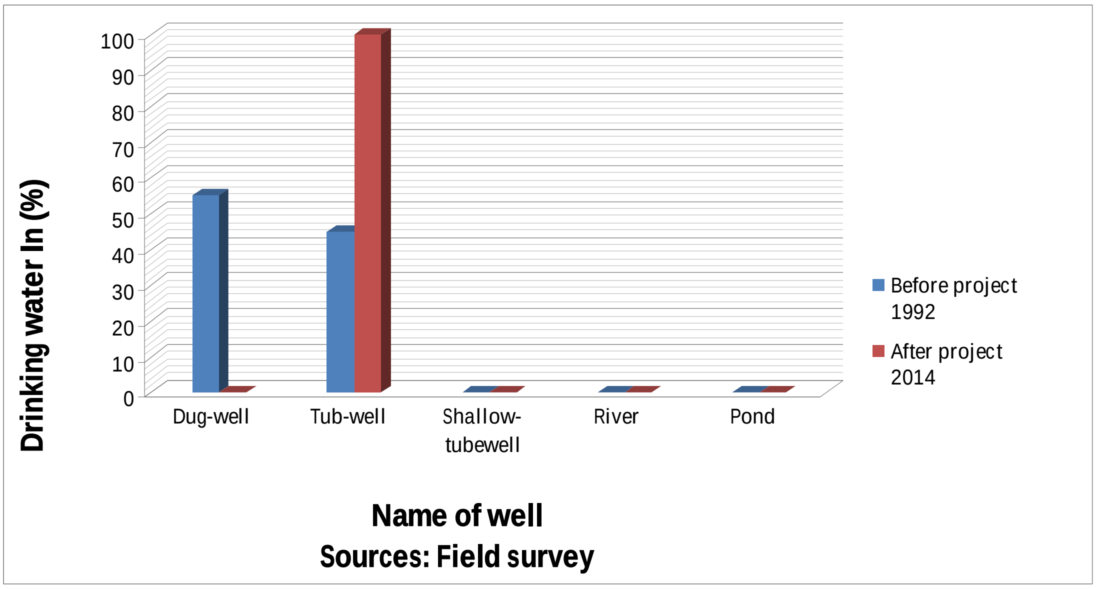

Figure 4.15: Changing of Drinking water pattern in project area (Kishorgonj Upzilla)

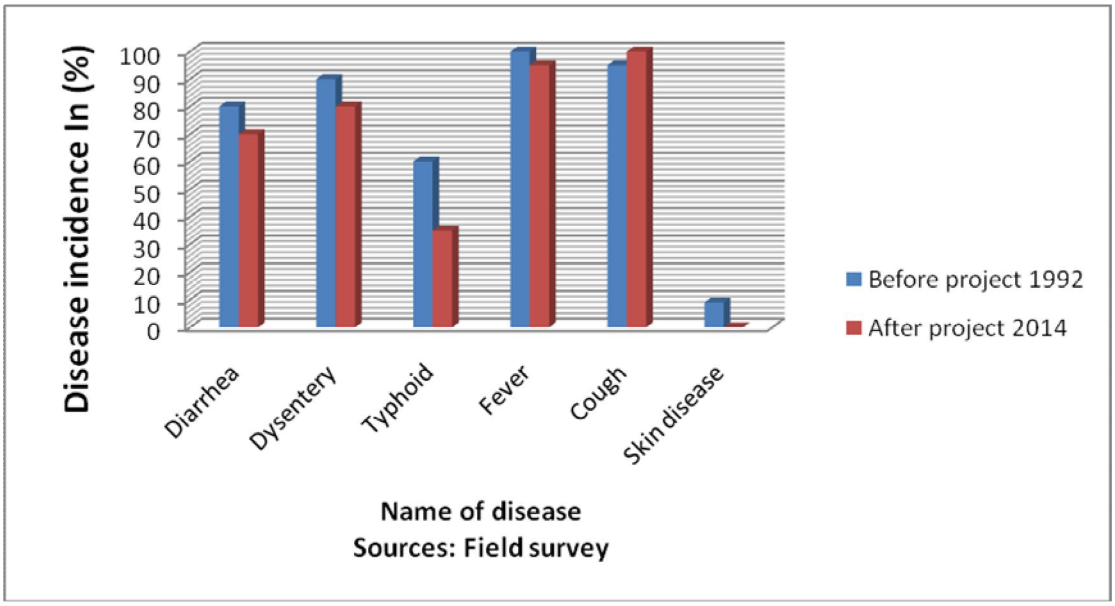

Figure 4.16: Changing of Human disease incidence in project area (Dimla Upzilla)

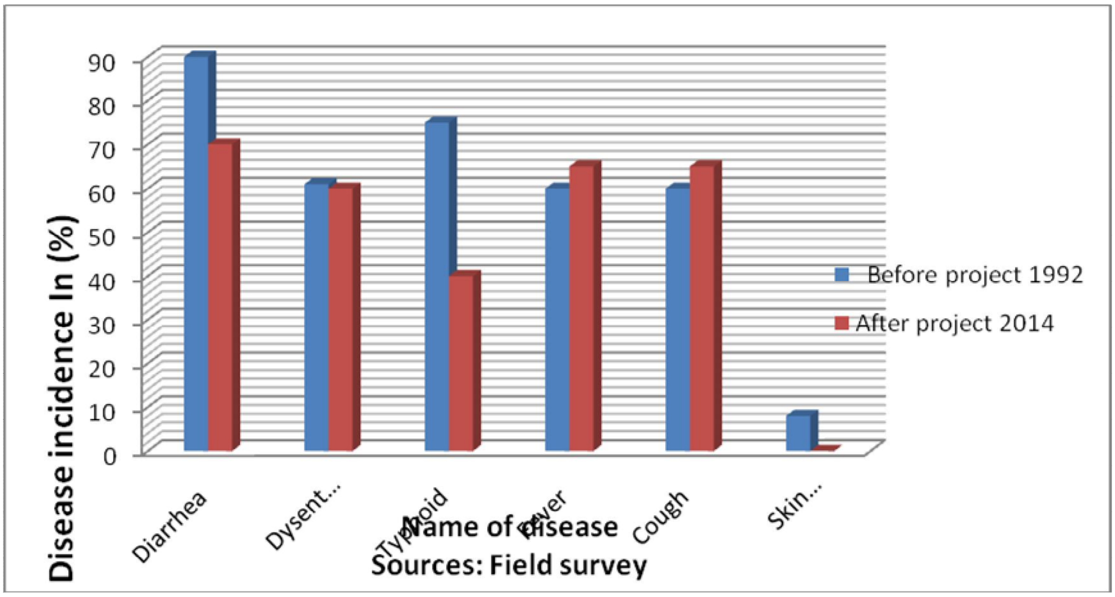

Figure 4.17: Changing of Human disease incidence in project area (Jaldhaka Upzilla)

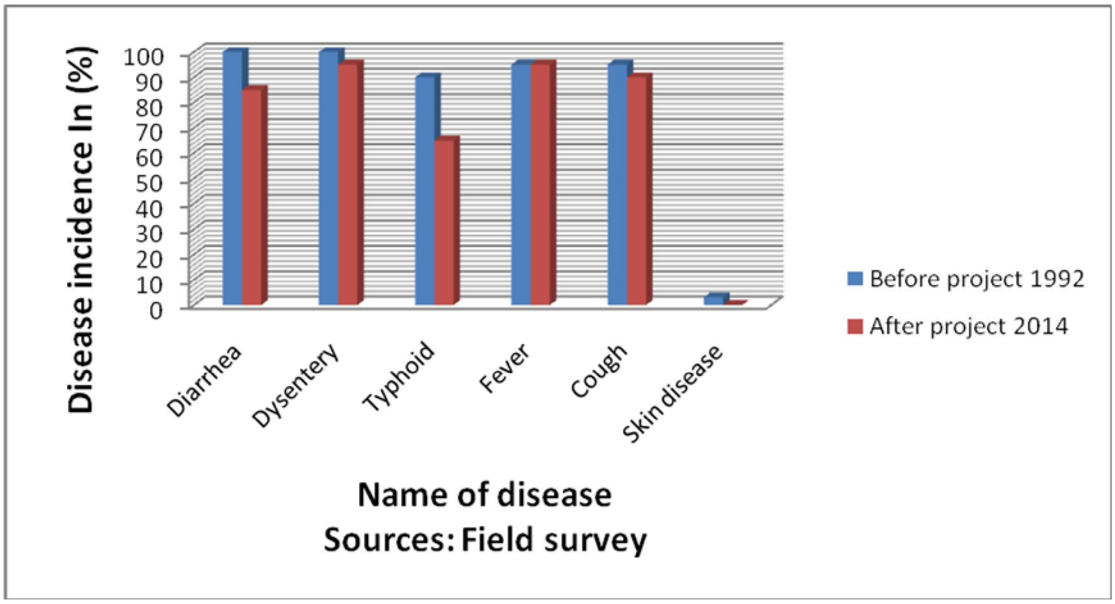

Figure 4.18: Changing of Human disease incidence in project area (Kishorgonj Upzilla)

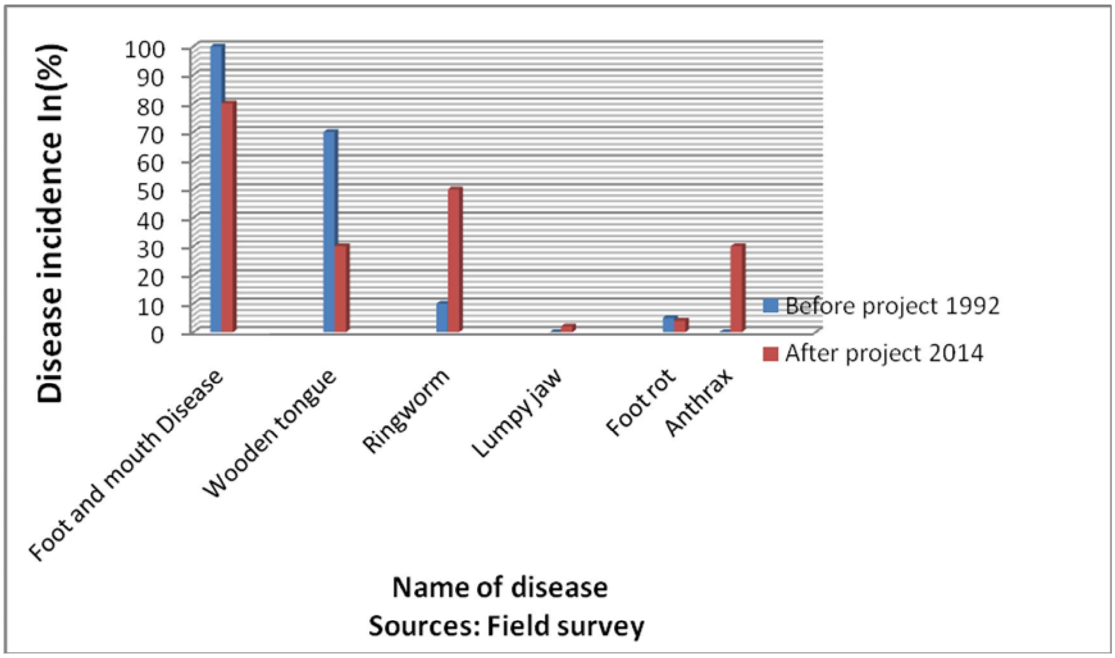

Figure 4.19: Changing of Livestock disease incidence in project area (Dimla Upzilla)

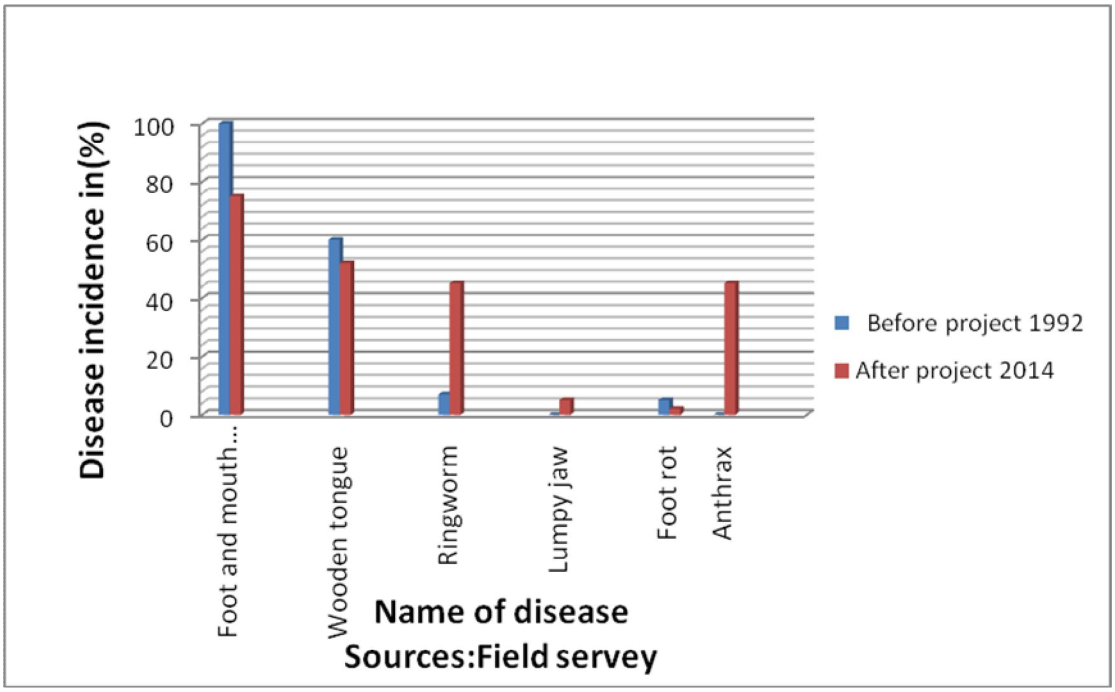

Figure 4.20: Changing of Livestock disease incidence in project area (Jaldhaka Upzilla)

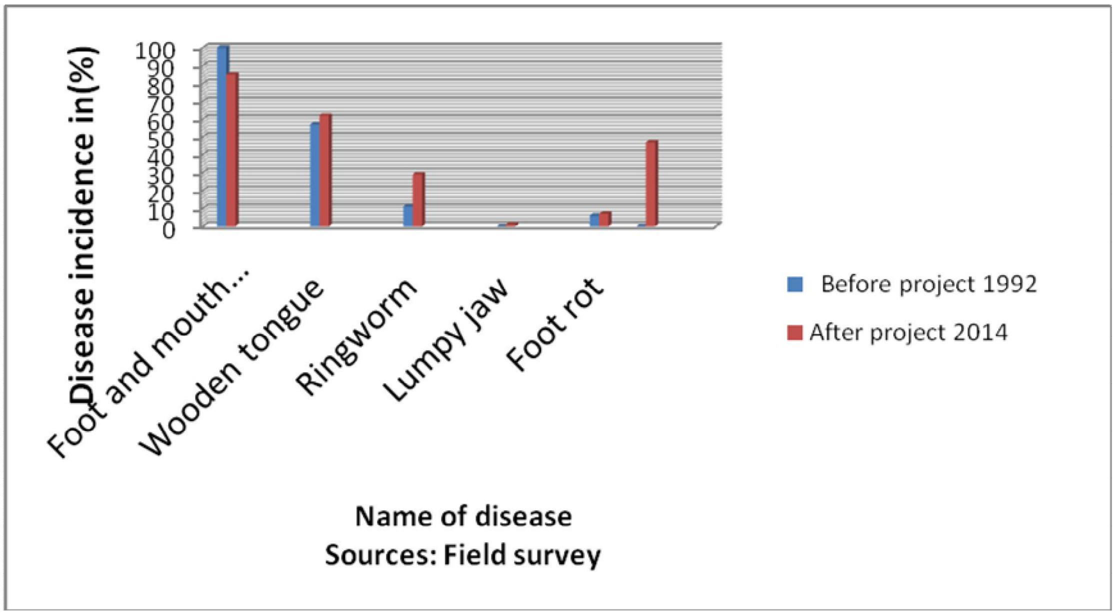

Figure 4.21: Changing of Livestock disease incidence in project area (Kishorgonj Upzilla)

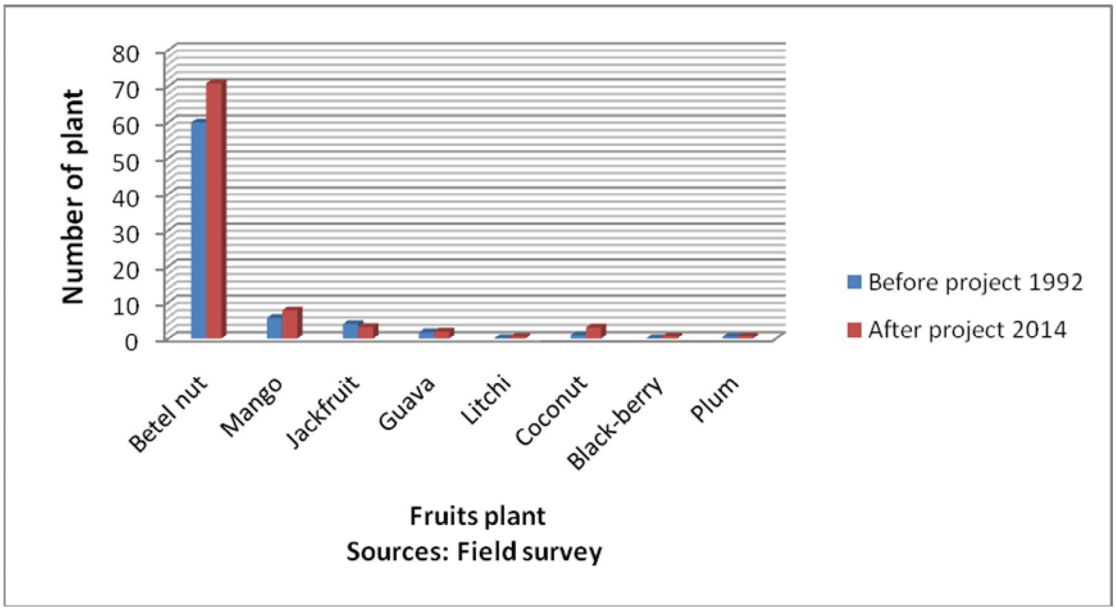

Figure 4.22: Changing of fruiting plants pattern in project area (Dimla Upzilla)

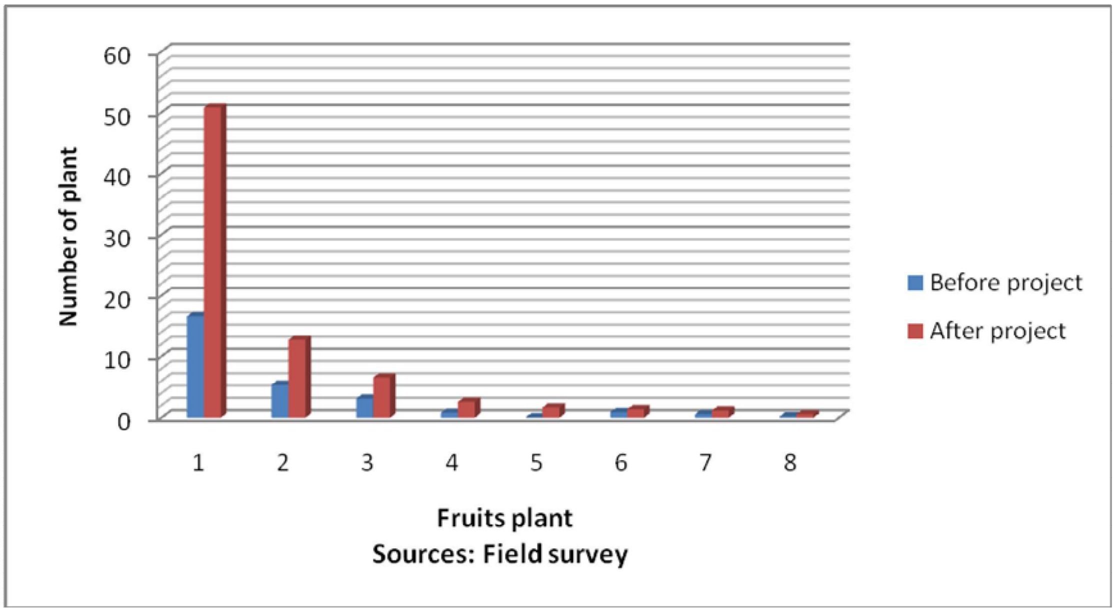

Figure 4.23: Changing of fruiting plants pattern in project area (Jaldhaka Upzilla)

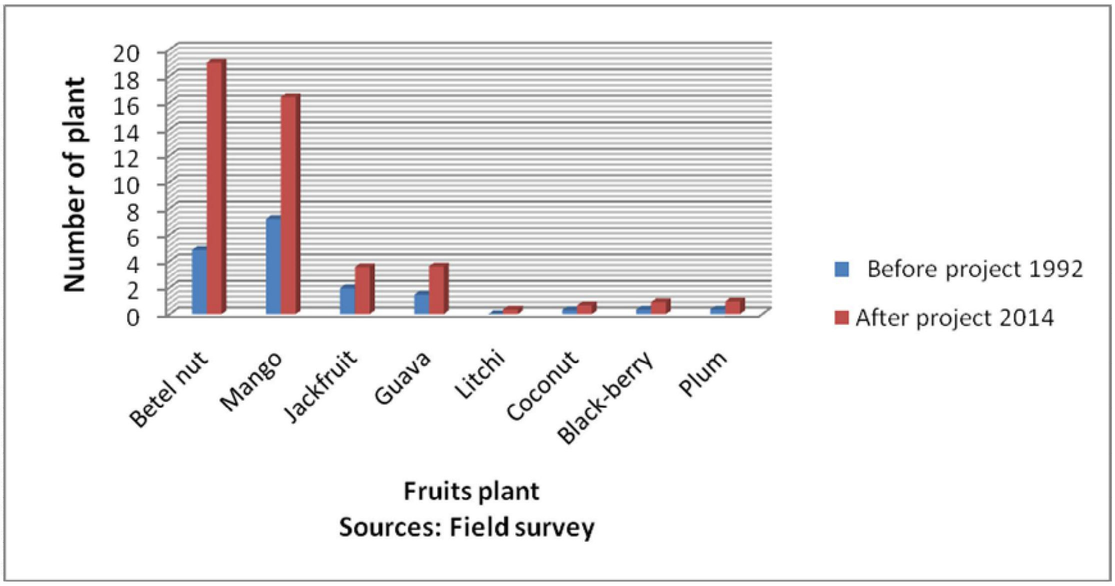

Figure 4.24: Changing of fruiting plants pattern in project area (Kishorgonj Upzilla)

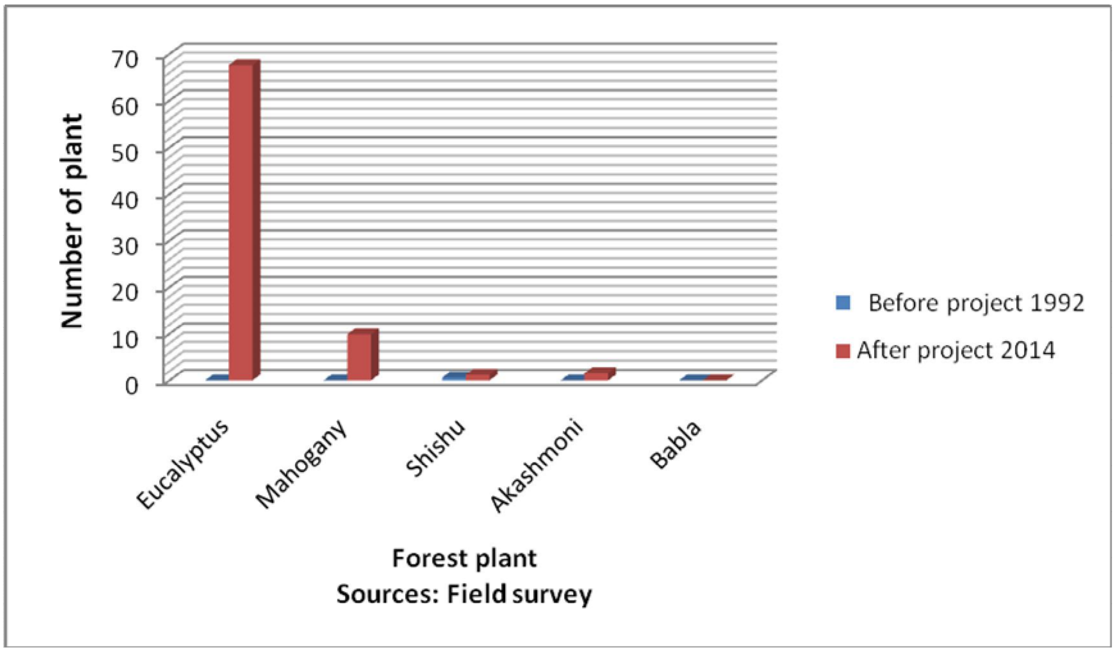

Figure 4.25: Changing of social forest plants pattern in project area (Dimla Upzilla)

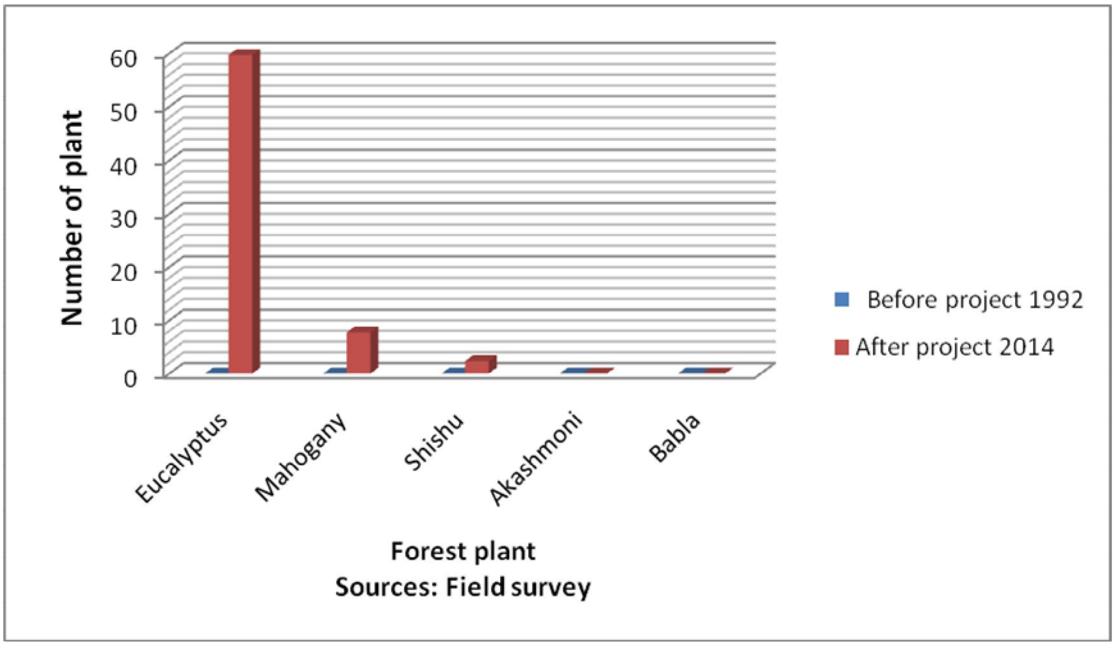

Figure 4.26: Changing of social forest plants pattern in project area (Jaldhaka Upzilla)

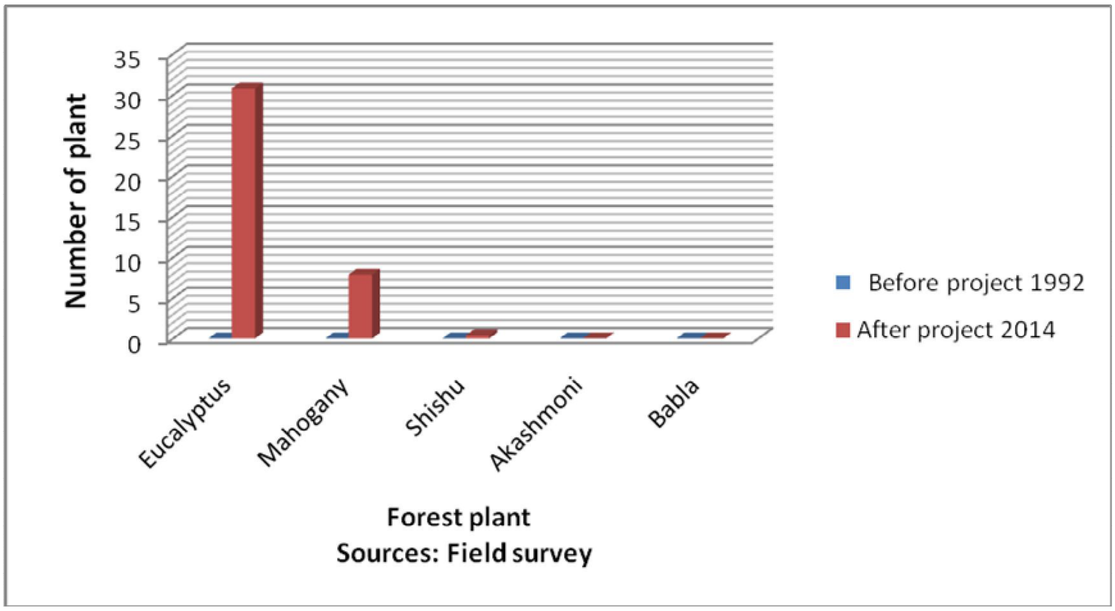

Figure 4.27: Changing of social forest plants pattern in project area (Kishorgonj Upzilla)

Figure 4.28: Teesta Barrage with irrigation regulator

Questionnaire Appendix-Chapter : 4

Teesta Barrage Project Impact on Environment

Date:

1. Name of Respondent Age. Vill. Thana

   Mobile No.

2. Agricultural Lands (bigha)

2.1 Cropping Intensity a) Before (1,2,3,4) b) After (1,2,3,4)

2.2 Cropping Pattern

Crops	Before Project	After Project
Kharif Crops		
Jut		
Aus		
Broadcasted Aman		
Transplanted Aman		
Sugarcane		
Turmeric		
Zinger		
Vegetables		
Winter Crops		
HYV Boro		
Wheat		
Corn/Maze		
Mustard		
Pulses		
Potato		
Sweet Potato		
Vegetables		
Tobacco		

3. Drinking water sources

1. Before Project
   a) Shallow-tube well b) Tube-well c) Dug-well d) River e) Pond

2. After Project
   a) Shallow-tube well b) Tube-well c) Dug-well d) River e) Pond

4. Human Disease Incidence

1. Before Project

   a) Cholera b) Diarrhea d) Typhoid e) Fever f) Cough

   g) Skin diseases h) Malaria

2. After Project

   a) Cholera b) Diarrhea d) Typhoid e) Fever f) Cough

   g) Skin diseases h) Malaria

5. Livestock Disease Incidence

1. Before Project

2. After Project

6. Fruiting and Social Forest Plants

Plants	**Before Project (Nos.)**	**After Project (Nos.)**
Fruiting plants		
Mango		
Jackfruit		
Guava		
Litchi		
Coconut		
Black-berry (jam)		
Plum (kul)		
Betel nut (Supari)		

Social Forest Plants		
Raintree		
Akashmoni		
Eucalyptus		
Shishu		
Babla		
Mahogany		

7. **Aqua Culture**

Aqua Culture	Before Project (Annual catch, kg)	After Project (Annual catch, kg)
Open Water Fisheries		
Open Water Fish Species		
Pond Area		
Culture Fish species in Pond		

8. **Pesticides Use Pattern**

Name of Pesticides	Before Project	After Project
DDT		
Diazinon		
Dimecron		

9. **Impact of Teesta Barrage Project on the society and environment**

a) Improved irrigation facilities (Yes/no/same)

b) Increased agriculture production (Yes/no/same)

c) Increased fish culture (Yes/no/same)

d) Improved flood protection (Yes/no/same)

e) Improved roads communication (Yes/no/same)

f) Improved safe drinking water sources (Yes/no/same)

g) Increased plantation (Yes/no/same)

h) Increased poultry farms (Yes/no/same)

i) Increased literacy rate (Yes/no/same)

j) Increased business opportunity (Yes/no/same)

k) Increased income (Yes/no/same)

l) Improved standard of life (Yes/no/same)