FINAL PROJECT

EFFICIENCY ANALYSIS OF WELLS IN GULFCOAST COUNTY USING DEA

Group Member:

Md Saffiquzzaman Chowdhury	(L20567403)
Deseyi John	(L20578544)
Jigarbhai Sonani	(L20578048)
Minhajul Abedin Tajik	(L20521113)

MAY 8, 2023

CVEN 5301: OPTIMIZATION FOR ENGINEERS

Submitted to: Dr. E. Annette Hernandez, PhD, PE

1. Introduction

1.1 Motivation for project

Groundwater nitrate refers to the presence of nitrate ($NO3^-$) in groundwater, which is water that exists beneath the Earth's surface in pores and spaces within soil and rocks. Nitrate is a naturally occurring compound that is essential for plant growth and is commonly found in fertilizers, animal manure, and human waste.

However, excessive levels of nitrate in groundwater can be harmful to human health, particularly in infants and young children, because it can interfere with the ability of red blood cells to carry oxygen. Nitrate contamination of groundwater can occur because of agricultural practices, leaky septic systems, and other human activities.

To ensure safe drinking water, it is important to monitor nitrate levels in groundwater and take steps to prevent contamination. This may include using fertilizers and other chemicals responsibly, properly maintaining septic systems, and implementing best management practices for agricultural activities. Agricultural practices: Nitrate is commonly used in fertilizers to enhance crop growth. Overuse or improper application of fertilizers can result in excess nitrate leaching into groundwater.

1.2 Objective

1. Use DEA to measure the efficiency of wells in Gulf coast County.
2. Identify the most and least efficient wells based on the DEA analysis.

1.3 Factors Affecting Nitrate Level in Ground Water:

1. Animal manure and wastewater: Livestock operations, as well as human wastewater treatment plants, can contribute to elevated levels of nitrate in groundwater if the manure or treated wastewater is not properly managed.
2. Septic systems: Leaking or poorly maintained septic systems can release nitrate into the surrounding groundwater.
3. Land-use changes: Changes in land use, such as urbanization or deforestation, can alter the balance of nitrogen in soil and water, leading to increased nitrate levels in groundwater.

4. Industrial activities: Industrial activities such as mining, manufacturing, and energy production may generate wastewater that contains elevated levels of nitrate, which can potentially contaminate groundwater.
5. Natural sources: Natural sources of nitrate, such as lightning strikes, wildfires, and microbial processes in soil and water, can also contribute to elevated levels of nitrate in groundwater.

The permissible limit for nitrate in drinking water varies depending on the country and the organization setting the standards. In the United States, the Environmental Protection Agency (EPA) has set a maximum contaminant level (MCL) of 10 milligrams per liter (mg/L) for nitrate-nitrogen in drinking water. This standard is based on the potential health effects of nitrate ingestion, particularly in infants and young children who are more susceptible to a condition known as methemoglobinemia or "blue baby syndrome".

In the European Union, the Drinking Water Directive has established a limit of 50 mg/L for nitrate in drinking water, although individual member states may set stricter standards. Other countries may have their own regulations and guidelines. It's important to note that while these limits are meant to ensure safe drinking water, it's still best to keep nitrate levels as low as possible to minimize potential health risks. Individuals who rely on private wells for drinking water may want to test their water regularly to ensure that nitrate levels are within safe limits.

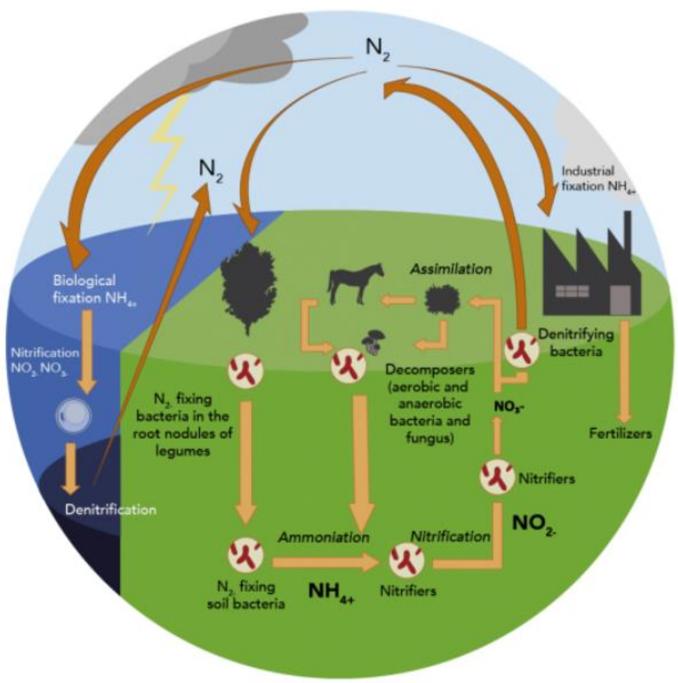

Figure 1: Nitrate cycle

2. Methodology

Groundwater nitrate contamination is a significant environmental and public health issue in many regions worldwide. To effectively manage and mitigate this issue, it is important to identify the most efficient well for nitrate removal. One way to do this is through data envelopment analysis (DEA) - a non-parametric method used to evaluate the relative efficiency of decision-making units (DMUs) that consume inputs and produce outputs. In this case, the DMUs are wells, the inputs are various site characteristics, and the output is nitrate removal efficiency.

The first step in this process is to download the metadata from https://www.twdb.texas.gov/ . which contains information on groundwater, surface water, water quality. Using R-code, the average nitrate concentration can be extracted and ordered along with other input variables, such as depth to water table, soil texture, and well depth. This information can be saved in a CSV file for further analysis.

Next, data filtering is necessary to ensure that only relevant data is included in the analysis. This may involve removing wells that are not currently in use or have incomplete data. It is also important to consider the spatial scale of the analysis and whether data from nearby wells should be included.

Once the data has been filtered and imported into the DEA R-model, the efficiency of each well can be evaluated. Wells that achieve the highest nitrate removal efficiency are considered the most efficient, as they can remove the greatest amount of nitrate per unit of input. The results of this analysis can be used to identify the most efficient well for nitrate removal and inform decision-making around management and mitigation strategies.

It is worth noting that DEA is just one approach to identifying the most efficient well. Additionally, the effectiveness of nitrate removal depends on many factors, including the specific well design and location, as well as external factors such as climate and land use. Therefore, it is important to approach this issue with a comprehensive and holistic perspective, using a range of tools and strategies to address the root causes of nitrate contamination in groundwater.

2.1 R-CODE: -

<u>**R-code for extract the dataset.**</u>

#Written by Deseyi Daniel John

#Filtering the wells in TWDB groundwater data

#Import necessary libraries

```
library (pivottabler)
```

#Setting working directory to the folder with original/extracted GWDB database

```
path<'C:\\Users\\desey\\OneDrive\\Desktop\\OPTIMIZATION\\FINALPROJECT\\GWDBDownload\\GWDBDownload'
```

```
setwd(path)
```

#Import master database of water quality in major aquifers

```
a <- read.csv('WaterQualityMajor.txt', sep = "|", quote = "", row.names = NULL, stringsAsFactors = FALSE)
```

#Filtering for Gulf Coast Aquifer Data

```
b <- a[a$Aquifer == "Gulf Coast",]
```

#Filtering for NITRATE NITROGEN, DISSOLVED, CALCULATED (MG/L AS NO3)

#71851 is the code for nitrate nitrogen

```
c <- b[b$ParameterCode == 71851,]
```

#Filtering for the data that are measured post 1980.

```
d <- c[c$SampleYear > 1980,]
```

#Extracting unique wells to separate variable

```
wells2 <- unique(d$StateWellNumber)
```

#Pivot Table to calculate average nitrate nitrogen for each wells

#If there is only sample point, no calculation necessary

#If more than one sample instances for same well, arithmetic mean is performed between all the measurements

pt <- PivotTable$new() #Initiating the pivot table

pt$addData(d) #Providing all the data

pt$addRowDataGroups("StateWellNumber”) #Provong unique rows

pt$defineCalculation(calculationName="Avg_Nitrate", summariseExpression="mean(ParameterValue, na.rm=TRUE)") #Get me average of parameter value

pt$defineCalculation(calculationName="No_of_Measurement", summariseExpression="n()") #COunt of nitrate measurement

pt$evaluatePivot() #Getering the pivot table

df <- pt$asDataFrame() #Extracting the pivottable as a dataframe

#Removing the last row with 'Total' row is added

df <- df[-nrow(df),]

#Import the Well Main File

wm <- read.csv ('WellMain.txt', sep = "|", quote = "", row.names = NULL, stringsAsFactors = FALSE)

#Getting only pre-defined unique wells with at least one nitrate measurement since 1980

wm2 <- wm [wm$StateWellNumber%in% wells2,]

#Arranging well-ID, No. of Measurement and Average Nitrate into a separate variable

nit <- data.frame(row.names(df),df$No_of_Measurement ,df$Avg_Nitrate)

colnames(nit) <- c("StateWellID","Count", "Avg_Nitrate")

#Dataframe with all necessary elements

df_all <- data.frame(wm2$StateWellNumber, wm2$LatitudeDD, wm2$LongitudeDD,nit$Count ,nit$Avg_Nitrate, wm2$WellDepth)

colnames(df_all) <- c("StateWellNumber","LatDD","LongDD","Meas_Count","Avg_Nit","Well Depth")

head(df_all)

#Removing rows with no data of well depth

df_all <- df_all[!is.na(df_all$`Well Depth`),]

#Removing rows with 0 value of Average Nitrate

df_all <- df_all[df_all$Avg_Nit !=0,]

#Plotting Nitrate_Nitrogen with Well-Depth

y <- df_all$Avg_Nit #Y variable

ylab <- c("Nitrate") #Y-axis label

x <- df_all$`Well Depth` #X-variable

xlab <- c("Well Depth") #X-axis label

plot(x,y , xlab = xlab, ylab = ylab) #Actual Plot

#Filtering out wells more than 100ft depth

df2 <- df_all[df_all$`Well Depth`<1000,]

nrow(df2[df2$Avg_Nit>3,]) # Checking Number of wells with Nit Concn > 3mg/L

#Export the dataframe as a csv file

write.csv(df2, "AVG_Nitrate.csv", row.names = FALSE)

R-code for DEA

```
path <- 'F:/Lamar University Spring 2023 Semester/Optimization/final project/trial'
```

 # Path of the working directory

```
setwd(path) # set working directory

getwd ()

library(readxl)

CCR_data_file <- read_excel ('F:/Lamar University Spring 2023 Semester/Optimization/final project/NitrateAV.xlsx')

View(CCR_data_file)

require(deaR)

ccr_model<-read_data(CCR_data_file, ni=9, no=1, dmus = 1, inputs=6:14, outputs=5)

View(ccr_model)

result_ccr <- model_basic(ccr_model, orientation = 'io', rts = 'crs', dmu_eval = 1:1197, dmu_ref=1:1197)

View(result_ccr)

efficiencies(result_ccr)

targets((result_ccr))

write.csv(targets(result_ccr), 'target.csv')

eff <-efficiencies((result_ccr))

write.csv(eff, 'eff.csv')

summary(result_ccr)

results <- summary(result_ccr)

write.csv(results, 'summary.csv')

plot(result_ccr)
```

 # Load the efficiency scores

efficiencies <- efficiencies(result_ccr)

 # Find the minimum and maximum efficiency scores

min_efficiency <- min(efficiencies)

max_efficiency <- max(efficiencies)

 # Find the DMUs with the minimum and maximum efficiency scores

min_efficient_dmus <- which(efficiencies == min_efficiency)

max_efficient_dmus <- which(efficiencies == max_efficiency)

 # Print the results

cat("Minimum efficient DMUs:", min_efficient_dmus, "\n")

cat("Maximum efficient DMUs:", max_efficient_dmus, "\n")

 # Get the efficiency scores

eff <- efficiencies(result_ccr)

 # Find the index of the maximum efficient DMU

max_eff_index <- which.max(eff)

 # Find the index of the minimum efficient DMU

min_eff_index <- which.min(eff)

 # Convert the maximum efficient DMU result value to 1 and the minimum efficient DMU value to 0

eff[eff == eff[max_eff_index]] <- 1

eff[eff == eff[min_eff_index]] <- 0

Print the updated efficiency scores eff

write.csv(eff, 'adjustmentfile.csv')

3. Result

The table 1 below shows top six DMUs, with DMU 6415301 as the most efficient well location with the value of 1.

Table 2 shows the least six inefficient DMUs. DMU 6606614 is the least efficient DMU with an efficiency value of 0.

Table 1

Most Efficient DMUs	
DMU	**Efficiency Value**
6415301	1.000000000000000
8704402	0.999999999999995
8744203	0.999999999999993
7929902	0.999999999999982
8727803	0.999999999999278
7907703	0.999999999997776

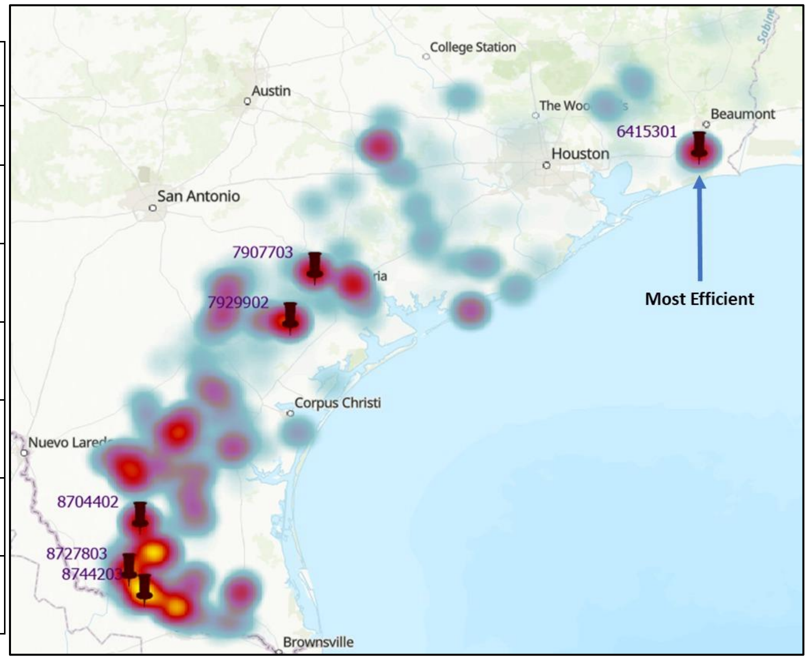

Figure 2 Most efficient wells

Table 2

Least Efficient DMUs	
DMU	**Efficiency Value**
6628609	0.0000588702
6203306	0.0000582442
7840903	0.0000574391
6601935	0.0000573835
6032217	0.0000562250
6606614	0.0000000000

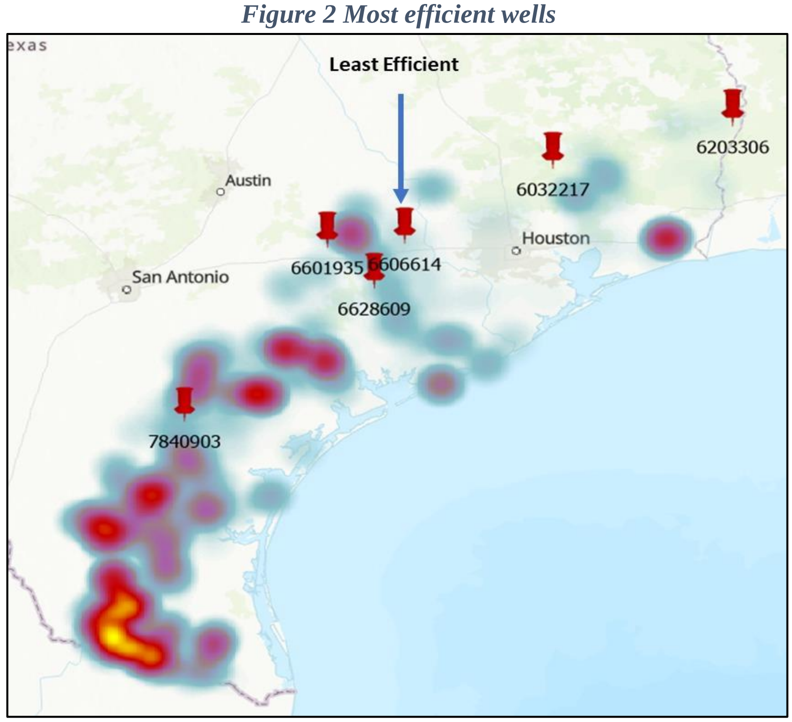

Figure 3 Least efficient wells

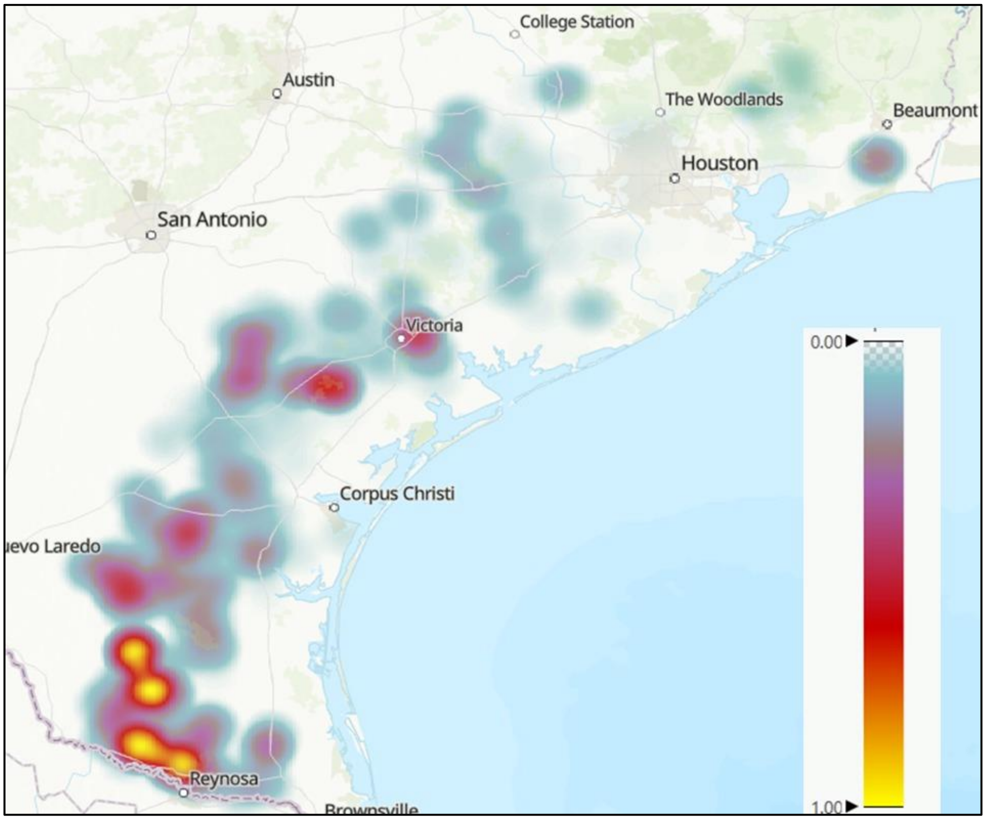

Figure 4 Heat map for weighted avg nitrate value

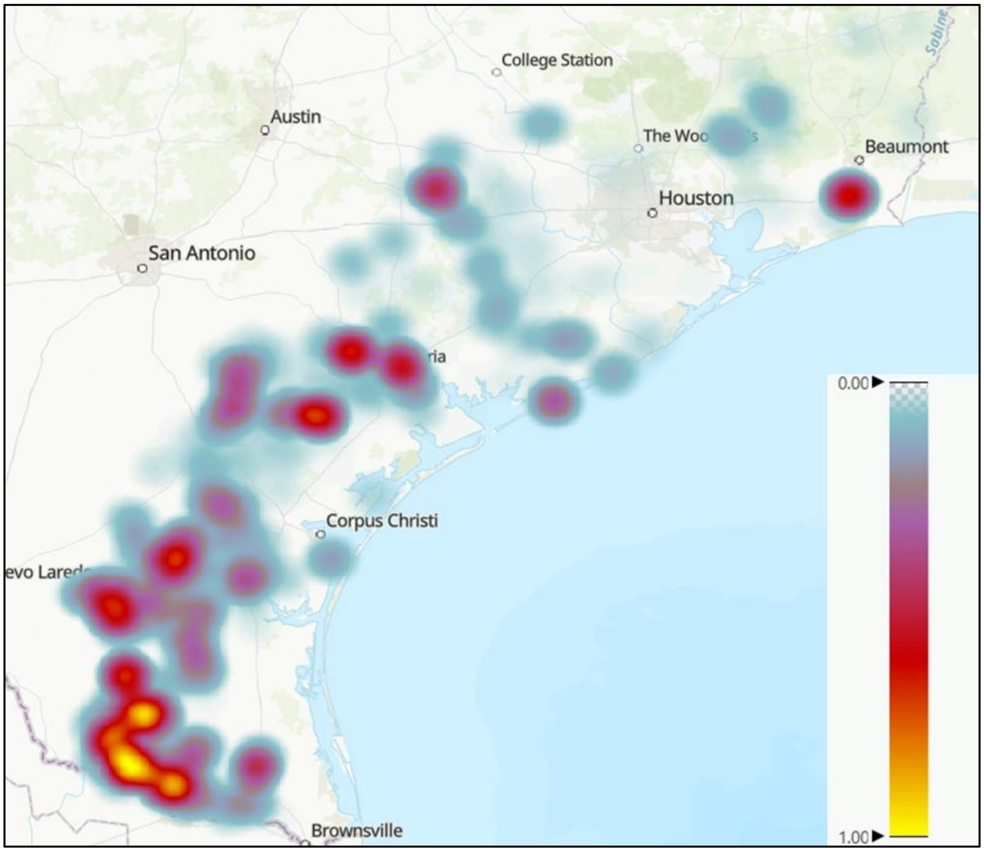

Figure 5 Efficiency of wells

4. Discussion

After the result, we had discussion session and try to find some solution to reduce nitrate level in ground water to overcome this situation and enhance quality of ground water. Possible solutions are mentioned below:

1) Reduce Nitrogen Use: One of the major sources of nitrate contamination in well water is from the use of nitrogen-based fertilizers in agriculture. Therefore, reducing the use of nitrogen-based fertilizers can significantly decrease nitrate levels in groundwater.
2) Proper Wastewater Management: Septic systems can also be a major source of nitrate contamination in well water. Proper maintenance and management of septic systems can help reduce the risk of contamination.
3) Precision Farming: Using precision farming techniques, such as variable rate fertilization, can help farmers optimize the use of nitrogen-based fertilizers and reduce nitrate runoff. This can help reduce the amount of nitrogen that enters the groundwater.
4) Crop Rotation: Alternating crops can help reduce nitrate levels in the soil. Different crops have different nitrogen requirements, so alternating crops can help prevent the buildup of excess nitrogen in the soil.
5) Treatment Systems: Installing a water treatment system can effectively remove excess nitrate from well water. Reverse osmosis systems, ion exchange systems, and distillation systems are all effective at removing nitrate from water.
6) Education and Outreach: Educating the public about the risks associated with nitrate contamination in well water and encouraging them to take preventative measures, such as regular testing and treatment of their water supply, can also be an effective way to reduce exposure to nitrate.

5. Appendix

- https://www.twdb.texas.gov/ (Final Project Dataset's Website)

Last lecture DEA work:

		Railways			Roadways							
Year	**Energy in TJ**	**PKM in billions**	**TKM in billions**	**Energy in TJ**	**PKM in billions**	**TKM in billions**	**Efficiency Railways**	**Effiecency Roadways**	**nu -input**	**constrain 1**	**L.H.S**	**R.H.S**
1980 to 81	276547	209	159	442590	353	98	0.3201	0.6810	1.4831E-06	1980 to 81	0.215506418	0
1981 to 82	288503	221	174	459360	377	103	0.3244	0.6921	**mu for PKM**	1981 to 82	0.215462791	0
1982 to 83	284951	227	178	498588	408	106	0.3374	0.6639	0.0004	1982 to 83	0.251986622	0
1983 to 84	275747	223	178	530511	448	116	0.3425	0.6834	**mu for TKM**	1983 to 84	0.252733511	0
1984 to 85	259278	227	182	573339	486	124	0.3708	0.6783	0.0030	1984 to 85	0.276549593	0
1985 to 86	254974	241	206	627644	850	193	0.4003	1.0000	**obj**	1985 to 86	3.33067E-15	0
1986 to 87	233496	257	223	683686	893	210	0.4662	0.9862	1.0140	1986 to 87	0.014000339	0
1987 to 88	223517	269	231	755410	980	238	0.5097	1.0000		1987 to 88	-9.99201E-15	0
1988 to 89	207529	264	230	829482	905	275	0.5406	1.0000		1988 to 89	0.027543994	0
1989 to 90	196795	281	237	916163	NA	NA	0.6048			1989 to 90	0	0
1990 to 91	183191	296	243	939671	NA	NA	0.6844			1990 to 91	0	0
1991 to 92	174779	315	257	1006974	NA	NA	1.3100			1991 to 92	0	0
1992 to 93	151194	300	258	1076886	NA	NA	0.8404			1992 to 93	0	0
1993 to 94	125367	296	257	1145102	1500	350	1.0000	0.98412411		1993 to 94	0.02696316	0
CARG80 to 94	(%) - 5.49	2.52	3.49	7.03	10.89	9.52				**constrain 2**	1	1

Work Contribution:

- **Introduction:** Jigarbhai Sonani, Deseyi John, Minhajul Abedin Tajik, Md Saffiquzzaman Chowdhury
- **Data Collection:** Deseyi John
- **Data Filtering:** Deseyi John, Jigarbhai Sonani, Minhajul Abedin Tajik, Md Saffiquzzaman Chowdhury
- **R-Coding:** Md Saffiquzzaman Chowdhury, Minhajul Abedin Tajik, Jigarbhai Sonani, Deseyi John
- **Map Creation:** Minhajul Abedin Tajik, Md Saffiquzzaman Chowdhury, Jigarbhai Sonani, Deseyi John
- **Discussion:** Md Saffiquzzaman Chowdhury, Minhajul Abedin Tajik, Jigarbhai Sonani, Deseyi John