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by Bandaranayake Mudiyanselage Hasitha Piyumal Bandaranayake

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INTRODUCTION

Sri Lanka's electricity demand is increasing day by day. But the Ministry of Energy in this country is unable to supply the demand. This assignment is based on a research project presented by the Ministry of Electricity and Renewable Energy to solve the energy problem in Sri Lanka. The task is as follows. Building structural factors related to the shape of a building determine the time it takes to cool the building and the duration of cooling. If these factors are in place in a building, chillers can operate more efficiently and use less electricity. Otherwise, the electricity is completely wasted. This contributes significantly to the overall electricity demand. A dataset named "energy_efficiency_data.csv" containing the above structural factors is provided.

In the first and second task, accurate statistical models are created based on the structural factors and cooling factors of a building using the R programming language and the data set mentioned above and data analysis is performed. At the end of this analysis, it is hoped to identify the relationships between cooling systems, building structures and energy consumption. The main objective is to reduce Sri Lanka's energy demand and increase energy efficiency.

In the third task, using the "SLWindPowerLand_21_23.csv" data set, a visual representation of the feasible land for the construction of new wind power plants in Sri Lanka is created. The QGIS application is used to accomplish this task. Here, the viable lands available in each district is shown on a map.

In the fourth task, suitable land for solar power plant construction is displayed on a map using the given data as in the third task above. Districts are classified and represented on a map based on the estimated total energy generation of each district. Details like district name, total area, etc. appear on the map.

In the fifth task, the Google Earth aerial image or information about solar power plants and buildings on the map is digitized using QGIS.

In the sixth task, a database is created in the PostgreSQL application using statistical data including monthly petrol and diesel consumption. This database includes the number of sheds, average diesel usage and average petrol usage for each district. A classification map is created with this data.

In the seventh task, suitable sites for renewable energy generation in Sri Lanka are identified using Google Earth and mapped using QGIS.

In the final task, a suitable land is selected for the construction of a regional research centre in the Kandy area and a map containing information about the area and the suitable area is displayed using QGIS.

QUESTION A

Analyzes how factors such as cooling systems and building structures affect energy consumption. The purpose of this machine is to cool buildings more efficiently and reduce electricity demand. Here R-studio application is used to perform this analysis. The variables in the data set can be divided into categorical and continuous.

1.1. Essential steps before data analytics

First the file containing the dataset needs to be uploaded to R-Studio. As a mandatory step, data cleaning should be done next. In this step, the null values in the data set are removed. After that we can start analyzing the data. Below are the codes used for that.

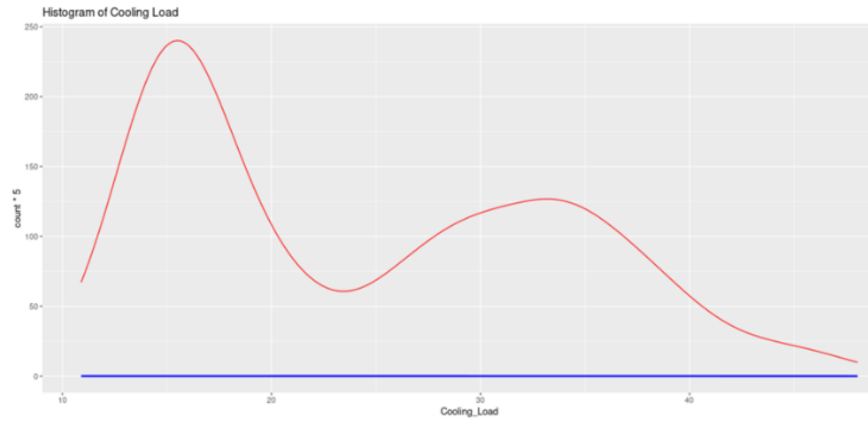
```
# Read the data set
unclean.data <- read.csv("energy_efficiency_data.csv")

# Remove null values
data <- na.omit(unclean.data)
```

Continuous Variables	Categorical Variables
Relative_Compactness	Orientation
Surface_Area	Glazing_Area_Distribution
Wall_Area	-
Roof_Area	-
Overall_Height	-
Glazing_Area	-
Heating_Load	-
Cooling_Load	-

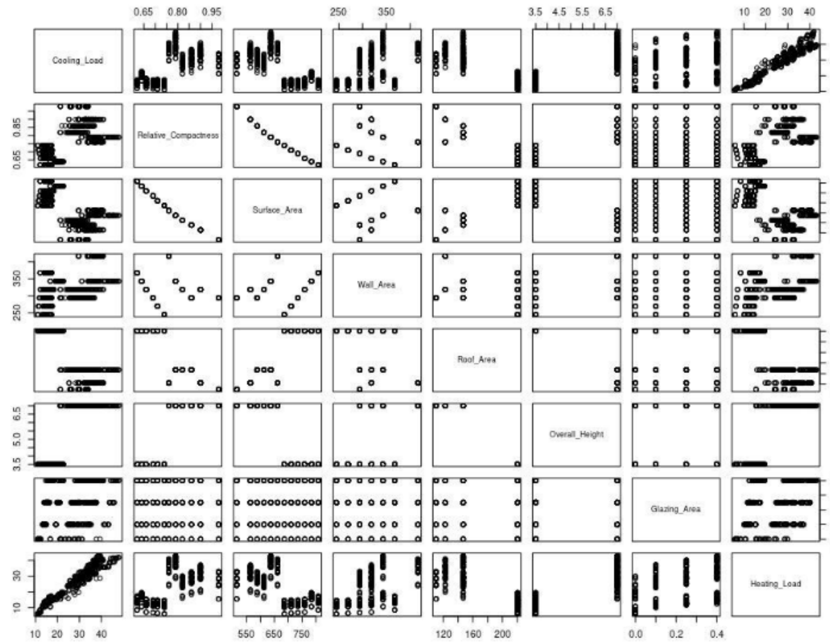
The above shows that the variables in the input data set are categorical and continuous.

1.2. Bell curve for Cooling Load



The figure above shows a bell curve showing the distribution of data in the data set used for this data analysis. This curve was created using the standard deviation of the data file. The peak of this bell curve represents the average value or mean. This can also be described as a multivariate distribution.

1.3. Scatter Plot



Above is a scatterplot drawn including structural factors affecting the cooling of a building. Here the main objective is to show the relationship between the cooling load and the relevant structural factor. According to the figure above, the connections are as follows. As the first relationship there is a positive relationship between the cooling load and the heating load. There is a negative relationship between the variables surface area and relative compactness, wall area and relative compactness. Finally, there is a positive relationship between surface area and wall area.

1.4. Create Model

```
# simple linear regression
lm_model <- lm(Cooling_load ~ Relative_Compactness + Surface_Area + Wall_Area + Roof_Area +
               Overall_Height + Glazing_Area + Heating_Load, data = data)
```

A model should be developed to examine the relationship between Cooling_Load and other variables. The model created for that is shown above.

```
Call:
lm(formula = cooling_load ~ Relative_Compactness + Surface_Area +
    Wall_Area + Roof_Area + Overall_Height + Glazing_Area + Heating_Load,
    data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-4.7918 -1.1500 -0.1510  0.9017  7.5642

Coefficients: (1 not defined because of singularities)
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)          25.289819  12.875614   1.964 0.049875 *
Relative_Compactness -15.159815   7.049381  -2.151 0.031829 *
Surface_Area         -0.013280   0.011600  -1.145 0.252656
Wall_Area            -0.007544   0.004677  -1.613 0.107144
Roof_Area                   NA         NA      NA       NA
Overall_Height        0.702701   0.247163   2.843 0.004588 **
Glazing_Area         -2.734094   0.724517  -3.774 0.000173 ***
Heating_Load          0.858800   0.024099  35.636  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.96 on 761 degrees of freedom
Multiple R-squared:  0.9579,    Adjusted R-squared:  0.9575
F-statistic:  2883 on 6 and 761 DF,  p-value: < 2.2e-16
```

In accordance with the model created above the relationship between Cooling_Load and the above-mentioned variables is analyzed below. Below is the summary of the linear regression model. This confirms the relationships in the scatterplot presented earlier. The relationships thus identified can be stated as follows. They are the variables Cooling_Load along with Glazing_Area, overall_Height, Relative_compactness, Heating Load. On this summary it appears that there is a very good relationship between Cooling_Load and Heating Load.

1.5. Identifying Relationships

1.5.1. Cooling Load and Heating Load Relationship

H0: There is no significant relationship between the cooling load and the heating load of the building.

H1: There is a significant relationship between the cooling load and the heating load of the building.

```
        Pearson's product-moment correlation

data:  data$Cooling_Load and data$Heating_Load
t = 123.67, df = 766, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.9722375 0.9790180
sample estimates:
      cor
0.9758618
```

As shown in the figure above, the P-value corresponding to the two variables Cooling_Load and Heating_Load is 2.2e-16. The significance level is 0.05. This means that there is a good correlation between these 2 variables and therefore the null hypothesis can be removed.

1.5.2. Cooling Load and Glazing Area Relationship

H0: There is no significant relationship between the cooling load and the Glazing Area of the building.

H1: There is a significant relationship between the cooling load and the Glazing Area of the building.

```
        Pearson's product-moment correlation

data:  data$Cooling_Load and data$Glazing_Area
t = 5.8708, df = 766, p-value = 6.457e-09
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.1387982 0.2742237
sample estimates:
     cor
0.207505
```

As shown in the figure above, the P-value corresponding to the two variables Cooling_Load and Glazing Area is 6.457e-09. The significance level is 0.05. This means that there is a good correlation between these 2 variables and therefore the null hypothesis can be removed.

1.5.3. Cooling Load and Overall Height Relationship

H0: There is no significant relationship between the cooling load and the Overall Height of the building.

H1: There is a significant relationship between the cooling load and the Overall Height of the building.

```
        Pearson's product-moment correlation

data:  data$Cooling_Load and data$Overall_Height
t = 55.777, df = 766, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.8808626 0.9089291
sample estimates:
      cor
0.8957852
```

The P-value corresponding to the two variables Cooling_Load and Overall Height is 2.2e-16. The significance level is 0.05. This means that there is a good correlation between these 2 variables and therefore the null hypothesis can be removed.

1.5.4. Cooling Load and Relative Compactness Relationship

H0: There is no significant relationship between the cooling load and the Overall Height of the building.

H1: There is a significant relationship between the cooling load and the Overall Height of the building.

```
        Pearson's product-moment correlation

data:  data$Cooling_Load and data$Relative_Compactness
t = 22.71, df = 766, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.5900749 0.6748011
sample estimates:
      cor
0.6343391
```

Considering Cooling_Load and Relative_Compactness, p-value = 2.2e-16 and the value is less than 0.05, so it seems that there is a good relationship between Cooling_Load and Relative_Compactness. Therefore, the null hypothesis is rejected, and the Alternative Hypothesis is confirmed to be correct.

QUESTION B

In this work, a statistical model is developed for the relationships identified in the first method above. The main purpose of this is to form this model of the relationships identified above and then present a summary statistic.

2.1. Cooling_Load and Heating_Load

```
> lm_model1 <- lm(data$Cooling_Load ~ data$Heating_Load,data = data)
> print(lm_model)

Call:
lm(formula = data$Cooling_Load ~ data$Heating_Load, data = data)

Coefficients:
      (Intercept)  data$Heating_Load
           4.0636             0.9201
```

$$Y\ data\$cooling\_Load = 4.0636 + 0.9201\ X\ data\$Heating\_Load$$

2.1.1. Summary Statistic for lm () Function

```
Call:
lm(formula = data$Cooling_Load ~ data$Heating_Load, data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-5.0849 -1.1504 -0.1884  0.6713  8.9244

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)        4.06361    0.18212   22.31   <2e-16 ***
data$Heating_Load  0.92007    0.00744  123.67   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.079 on 766 degrees of freedom
Multiple R-squared:  0.9523,    Adjusted R-squared:  0.9522
F-statistic: 1.529e+04 on 1 and 766 DF,  p-value: < 2.2e-16
```

According to the above summary statistics, there is a very strong correlation between the two variables Cooling_Load and Heating_Load. The P-value here is very small. That is 2.2e-16.

2.2. Cooling_Load and Glazing_Area

```
> lm_model1 <- lm(data$Cooling_Load ~ data$Glazing_Area,data = data)
> print(lm_model1)

Call:
lm(formula = data$Cooling_Load ~ data$Glazing_Area, data = data)

Coefficients:
      (Intercept)  data$Glazing_Area
            21.11              14.82
```

$$Y\ data\$cooling\_Load = 21.11 + 14.82\ X\ data\$Glazing\_Area$$

2.2.1. Summary Statistic for lm () Function

```
> summary(lm_model1)

Call:
lm(formula = data$Cooling_Load ~ data$Glazing_Area, data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-12.462  -9.049  -1.536   8.127  21.151

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)        21.1148     0.6803  31.036  < 2e-16 ***
data$Glazing_Area  14.8180     2.5240   5.871 6.46e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 9.312 on 766 degrees of freedom
Multiple R-squared:  0.04306,	Adjusted R-squared:  0.04181
F-statistic: 34.47 on 1 and 766 DF,  p-value: 6.457e-09
```

A p-value of 6.457e-09 was obtained for the relationship between Cooling_Load and Glazing_Area as in the above relationship.

2.3. Cooling_Load and Relative_Compactness

```
> lm_model1 <- lm(data$Cooling_Load ~ data$Relative_Compactness,data = data)
> print(lm_model1)

Call:
lm(formula = data$Cooling_Load ~ data$Relative_Compactness, data = data)

Coefficients:
              (Intercept)  data$Relative_Compactness
                   -19.01                      57.05
```

$$Y\ data\$cooling\_Load = -19.01 + \ 57.05X\ data\$Relative\_Compactnes$$

2.3.1. Summary Statistic for lm () Function

```
Call:
lm(formula = data$Cooling_Load ~ data$Relative_Compactness, data = data)

Residuals:
    Min      1Q  Median      3Q     Max 
-15.571  -5.632  -1.233   3.379  21.968 

Coefficients:
                          Estimate Std. Error t value Pr(>|t|)    
(Intercept)                -19.008      1.938  -9.809   <2e-16 ***
data$Relative_Compactness   57.051      2.512  22.710   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 7.359 on 766 degrees of freedom
Multiple R-squared:  0.4024,	Adjusted R-squared:  0.4016 
F-statistic: 515.8 on 1 and 766 DF,  p-value: < 2.2e-16
```

According to the summary statistics, there is a very strong correlation between the two variables Cooling_Load and Relative_Compactness. Here the P value is very small. That is 2.2e-16.

2.4. Cooling_Load and Overall_Height

```
> lm_model1 <- lm(data$Cooling_Load ~ data$Overall_Height,data = data)
> print(lm_model1)

Call:
lm(formula = data$Cooling_Load ~ data$Overall_Height, data = data)

Coefficients:
        (Intercept)  data$Overall_Height
            -0.9612               4.8665
```

$$Y\ data\$cooling\_Load = -0.9612 + 4.86X\ data\$Overall\_Hight$$

2.4.1. Summary Statistic for lm () Function

```
Call:
lm(formula = data$Cooling_Load ~ data$Overall_Height, data = data)

Residuals:
     Min       1Q   Median       3Q      Max
-11.9441  -2.3539  -0.2664   2.0386  14.9259

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)         -0.96122    0.48283  -1.991   0.0469 *
data$Overall_Height  4.86647    0.08725  55.777   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.231 on 766 degrees of freedom
Multiple R-squared:  0.8024,    Adjusted R-squared:  0.8022
F-statistic:  3111 on 1 and 766 DF,  p-value: < 2.2e-16
```

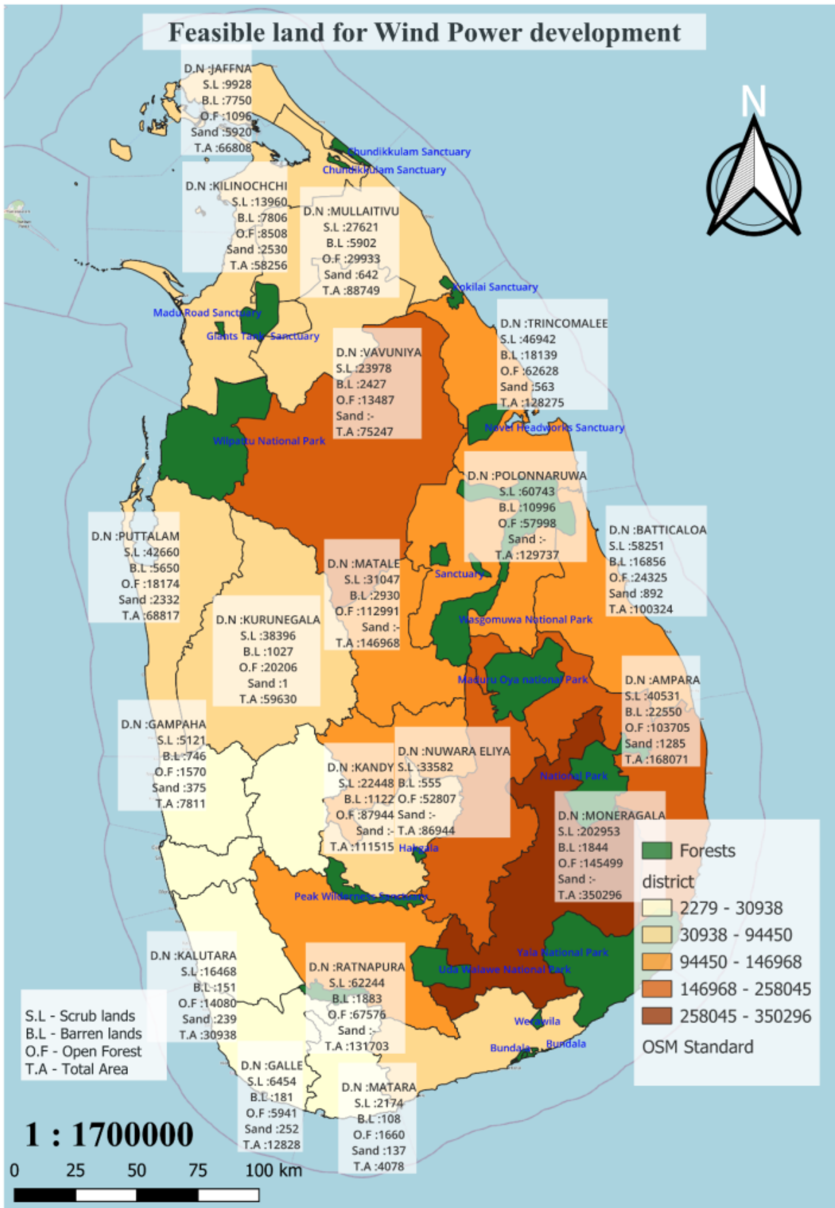
According to the summary statistics, there is a very strong correlation between the two variables Cooling_Load and Overall_Height. Here the P value is very small. That is 2.2e-16.

QUESTION C

Currently, the focus is on the use of renewable energy. In this chapter, attention is focused on wind energy as a renewable energy source and the search for suitable land for the development of wind power plants in Sri Lanka is carried out. Then the land suitable for the development of wind power plants is displayed on a map of Sri Lanka separately from district to district. This work is done using the dataset published by Sri Lanka Sunitya Energy Authority named "SLWindPowerLand_21_23.csv"(Rodrigo, n.d.). Below is a screenshot of the dataset I mentioned above.

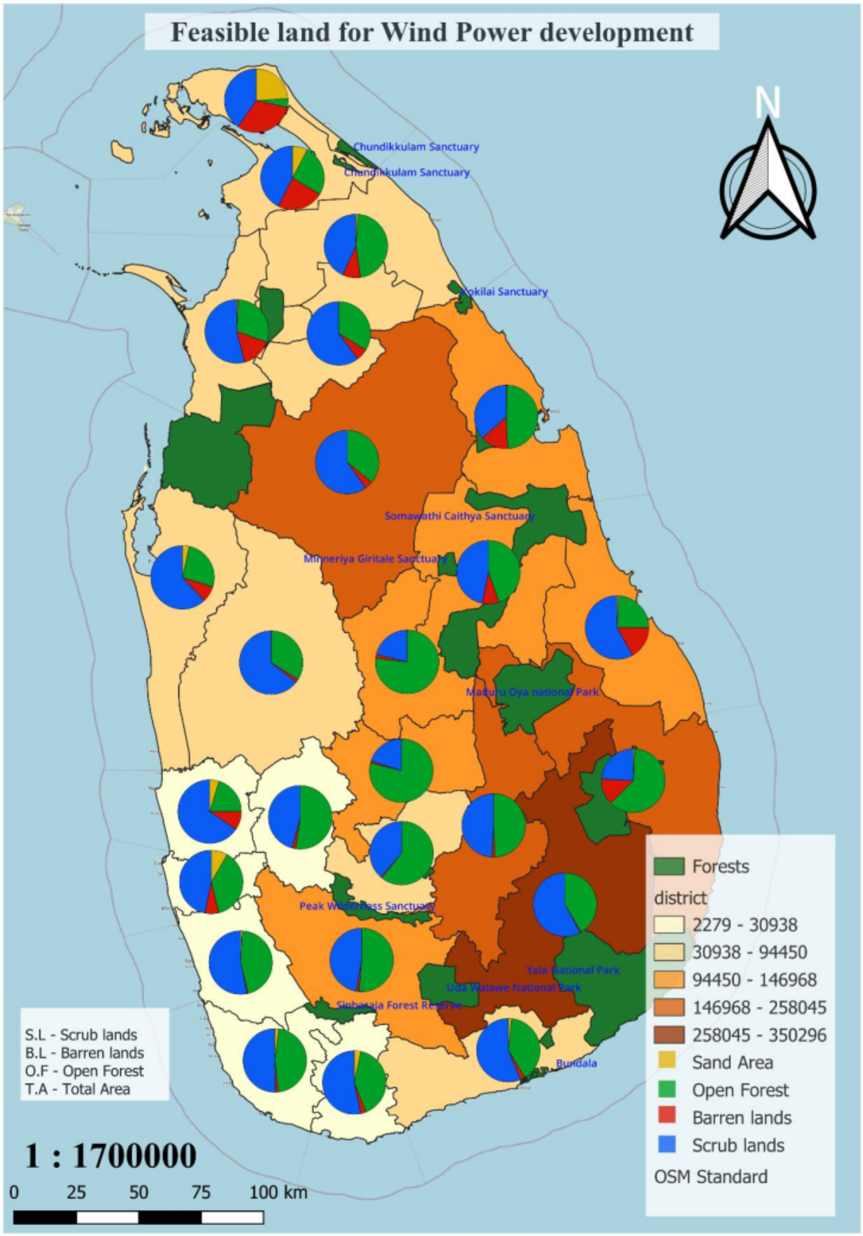
1	District	SCRBA	BRRNA	FRSOA	SANDA	HOMSA	SPRSA	GRSLA	PLMRA	CCNTA	Total
2	AMPARA	40531	22550	103705	1285	-	-	-	-	-	168071
3	ANURADHAPURA	117222	8154	70543	-	961	1143	-	-	3	198026
4	BADULLA	126647	3742	127656	-	-	-	-	-	-	258045
5	BATTICALOA	58251	16856	24325	892	-	-	-	-	-	100324
6	COLOMBO	1066	162	861	191	-	-	-	-	-	2279
7	GALLE	6454	181	5941	252	-	-	-	-	-	12828
8	GAMPAHA	5121	746	1570	375	-	-	-	-	-	7811
9	HAMBANTOTA	53217	2222	37456	1555	-	-	-	-	-	94450
10	JAFFNA	9928	7750	1096	5920	34778	3313	2449	701	874	66808
11	KALUTARA	16468	151	14080	239	-	-	-	-	-	30938
12	KANDY	22448	1122	87944	-	-	-	-	-	-	111515
13	KEGALLE	12522	469	14235	-	-	-	-	-	-	27226
14	KILINOCHCHI	13960	7806	8508	2530	17516	5742	21	469	1705	58256
15	KURUNEGALA	38396	1027	20206	1			-	-	-	59630
16	MANNAR	32532	9391	17940	465	8715	4523	227	737	849	75379
17	MATALE	31047	2930	112991	-	-	-	-	-	-	146968
18	MATARA	2174	108	1660	137	-	-	-	-	-	4078
19	MONERAGALA	202953	1844	145499	-	-	-	-	-	-	350296
20	MULLAITIVU	27621	5902	29933	642	16716	6505	402	-	1029	88749
21	NUWARA ELIYA	33582	555	52807	-	-	-	-	-	-	86944
22	POLONNARUWA	60743	10996	57998	-	-	-	-	-	-	129737
23	PUTTALAM	42660	5650	18174	2332	-	-	-	-	-	68817
24	RATNAPURA	62244	1883	67576	-	-	-	-	-	-	131703
25	TRINCOMALEE	46942	18139	62628	563	-	4	-	-	-	128275
26	VAVUNIYA	23978	2427	13487	-	21268	12934	1044	-	108	75247

A map of Sri Lanka with suitable land for wind power development shows the related explanation below.



Above is a map of Sri Lanka that visualizes information about potential land drawn using the given data set. This map is divided by districts. Districts on the map are colored in a range of colors from light to dark. Accordingly, the district with the strongest color is the most suitable district for wind power generation, and in comparison, the decrease in color in other districts implies that the feasibility of developing wind power plants is gradually decreasing. That is, the dark color shows the district with the highest potential for wind power development and the white color shows the least potential for wind power development. And the green color shows the existing forests in Sri Lanka. Also, open forest, scrub, wasteland and sand areas are grouped on the map.

According to the above map, there are several districts suitable for the development of wind farms. They are Anuradhapura, Monaragala, Ampara, Badulla. Before constructing a wind farm, a feasibility study is carried out in the area. The main requirements that are considered are as follows. Examples of these are spacing between wind turbines, setbacks from obstacles, access roads and infrastructure, wind resource variability, buffer zones, non-sand areas. Considering these factors, Monaragala can be said to be the most suitable district for the construction of wind power plants. Monaragala district has no sandy land and has a large area of 350296 hectares. That is, the basic requirements to build a wind farm are met.



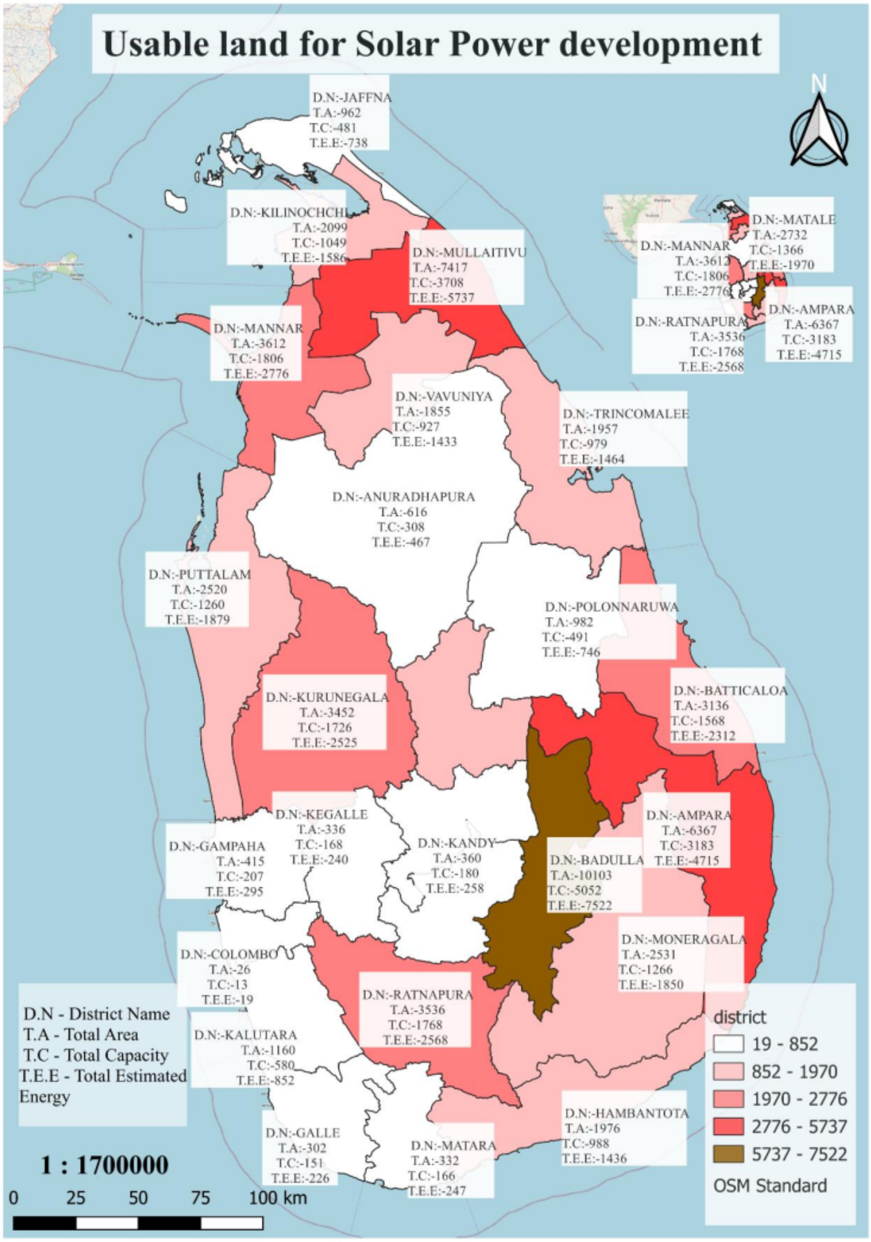
Feasible land for Wind Power development
Chundikkulam Sanctuary
Chundikkulam Sanctuary
Kokilai Sanctuary
Somawathi Caithya Sanctuary
Minneriya Giritale Sanctuary
Maduru Oya national Park
Peak Wilderness Sanctuary
Yala National Park
Uda Walawe National Park
Sinharaja Forest Reserve
Bundala
N
Forests
district
2279 - 30938
30938 - 94450
94450 - 146968
146968 - 258045
258045 - 350296
Sand Area
Open Forest
Barren lands
Scrub lands
OSM Standard
S.L - Scrub lands
B.L - Barren lands
O.F - Open Forest
T.A - Total Area
1 : 1700000
0 25 50 75 100 km

QUESTION D

As mentioned in the above chapter, solar energy can be called as another renewable energy. Sri Lanka is a country close to the equator. Therefore, the sun shines throughout the year. In this chapter, the data set provided by the Sri Lanka Renewable Energy Authority should be used to find and map the most suitable land to build the solar power plant in Sri Lanka. Using the given data, a data set is created which includes district, total capacity (MW), total area (ha), and total estimated energy (GWh) etc. Below is a screenshot of the data set I mentioned above.

	A	B	C	D	E	F	G
1	District	Total Area	Total Capacity	10MW<x<25MW	25MW<x<100MW	>100MW	Total estimated energy
2	AMPARA	6367	3183	536	835	1812	4715
3	ANURADHAPURA	616	308	35	273	-	467
4	BADULLA	10103	5052	831	2288	1933	7522
5	BATTICALOA	3136	1568	275	986	307	2312
6	COLOMBO	26	13	13	-	-	19
7	GALLE	302	151	35	116	-	226
8	GAMPAHA	415	207	117	90	-	295
9	HAMBANTOTA	1976	988	121	388	479	1436
10	JAFFNA	962	481	39	144	297	738
11	KALUTARA	1160	580	121	176	283	852
12	KANDY	360	180	74	106	-	258
13	KEGALLE	336	168	128	40	-	240
14	KILINOCHCHI	2099	1049	307	284	459	1586
15	KURUNEGALA	3452	1726	476	826	424	2525
16	MANNAR	3612	1806	394	586	826	2776
17	MATALE	2732	1366	206	438	722	1970
18	MATARA	332	166	29	137	-	247
19	MONERAGALA	2531	1266	136	584	546	1850
20	MULLAITIVU	7417	3708	719	1944	1046	5737
21	NUWARA ELIYA	495	247	50	198	-	375
22	POLONNARUWA	982	491	124	367	-	746
23	PUTTALAM	2520	1260	274	653	333	1879
24	RATNAPURA	3536	1768	572	1196	-	2568
25	TRINCOMALEE	1957	979	164	264	551	1464
26	VAVUNIYA	1855	927	252	470	205	1433

The above data set shows the power generation capacities of different districts. The energy requirement varies from district to district. It implies that power plant facilities have been provided from small size to large size in accordance with each district. The above table shows the contribution of each district to the total energy supply of the nation.


Usable land for Solar Power development
N
D.N:-JAFFNA
T.A:-962
T.C:-481
T.E.E:-738
D.N:-KILINOCHCHI
T.A:-2099
T.C:-1049
T.E.E:-1586
D.N:-MULLAITIVU
T.A:-7417
T.C:-3708
T.E.E:-5737
D.N:-MANNAR
T.A:-3612
T.C:-1806
T.E.E:-2776
D.N:-VAVUNIYA
T.A:-1855
T.C:-927
T.E.E:-1433
D.N:-TRINCOMALEE
T.A:-1957
T.C:-979
T.E.E:-1464
D.N:-ANURADHAPURA
T.A:-616
T.C:-308
T.E.E:-467
D.N:-PUTTALAM
T.A:-2520
T.C:-1260
T.E.E:-1879
D.N:-POLONNARUWA
T.A:-982
T.C:-491
T.E.E:-746
D.N:-KURUNEGALA
T.A:-3452
T.C:-1726
T.E.E:-2525
D.N:-BATTICALOA
T.A:-3136
T.C:-1568
T.E.E:-2312
D.N:-KEGALLE
T.A:-336
T.C:-168
T.E.E:-240
D.N:-GAMPAHA
T.A:-415
T.C:-207
T.E.E:-295
D.N:-KANDY
T.A:-360
T.C:-180
T.E.E:-258
D.N:-AMPARA
T.A:-6367
T.C:-3183
T.E.E:-4715
D.N:-BADULLA
T.A:-10103
T.C:-5052
T.E.E:-7522
D.N:-MONERAGALA
T.A:-2531
T.C:-1266
T.E.E:-1850
D.N:-COLOMBO
T.A:-26
T.C:-13
T.E.E:-19
D.N:-RATNAPURA
T.A:-3536
T.C:-1768
T.E.E:-2568
D.N:-KALUTARA
T.A:-1160
T.C:-580
T.E.E:-852
D.N:-HAMBANTOTA
T.A:-1976
T.C:-988
T.E.E:-1436
D.N:-GALLE
T.A:-302
T.C:-151
T.E.E:-226
D.N:-MATARA
T.A:-332
T.C:-166
T.E.E:-247
D.N:-MATALE
T.A:-2732
T.C:-1366
T.E.E:-1970
D.N - District Name
T.A - Total Area
T.C - Total Capacity
T.E.E - Total Estimated Energy
1 : 1700000
0 25 50 75 100 km
district
19 - 852
852 - 1970
1970 - 2776
2776 - 5737
5737 - 7522
OSM Standard

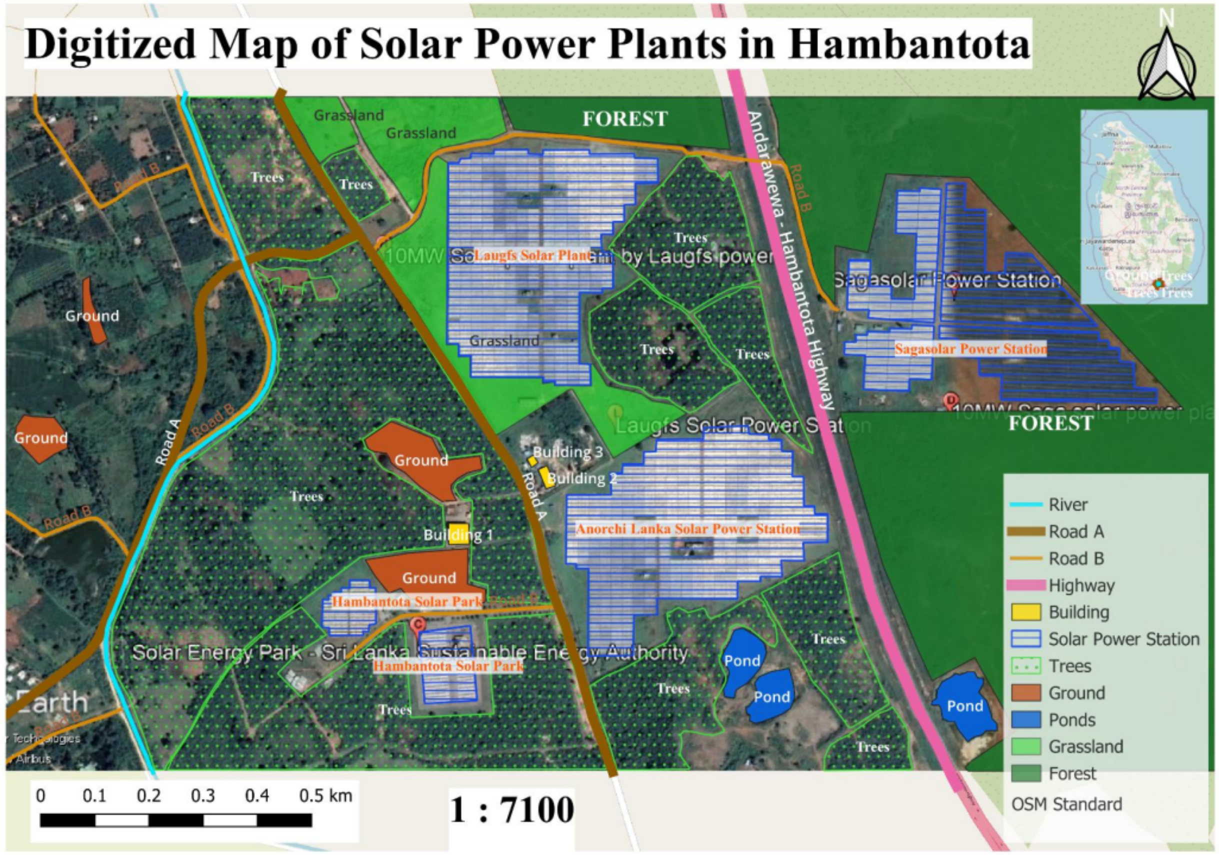
The above map shows a map of Sri Lanka divided according to the districts that include the land available for the construction of solar power plants. Districts are colored by estimated strength. It is clearly mentioned in the legend of the map. Mainly speaking, the district with the darkest color is the most suitable district for the generation of electricity from solar energy, and the decrease in the color of other districts in comparison shows that the feasibility of developing solar power plants is gradually decreasing. Districts with the least amount of energy produced by solar power plants are shown in white.

By studying the above map, the following conclusions can be drawn. We can see that Badulla district can generate a high amount of electricity in terms of energy if solar power plants are built in the above manner throughout the country. An amount of 10103 hectares of land has been identified in Badulla district. The Renewable Energy Authority has identified this as having a total capacity of 5052 MW with an estimated total energy of 7522GWh. Compared to Badulla, the next most suitable districts to produce the most electricity are Ampara and Mullaitivu. The estimated total energy of these two districts is 4715GWh and 5737GWh respectively. According to the map, the second largest energy producing district is Ampara and the third is Mullaitivu.

By gaining an understanding of these processes, Sri Lanka's electricity supply can be further developed by using the country's resources efficiently. It can bring reliable energy supply across the country.

QUESTION E

This chapter uses GIS tools and Google Earth imagery to develop and explore a digital map for the integration of solar power plants in an island energy landscape. This map shows roads, trees, solar facilities, buildings, and forests in different layers. The main purpose of analyzing spatial relationships is to demonstrate how solar power can contribute to improving energy security and fueling economic growth. This chapter critically examines the progress in the use of solar energy to overcome challenges in the energy sector


Digitized Map of Solar Power Plants in Hambantota
N
FOREST
FOREST
Grassland
Grassland
Grassland
Trees
Laugfs Solar Plant
Anorchi Lanka Solar Power Station
Sagasolar Power Station
Sagasolar Power Station
Hambantota Solar Park
Hambantota Solar Park
Solar Energy Park - Sri Lanka Sustainable Energy Authority
Andarawewa - Hambantota Highway
Building 1
Building 2
Building 3
Road A
Road B
Ground
Pond
River
Road A
Road B
Highway
Building
Solar Power Station
Trees
Ground
Ponds
Grassland
Forest
OSM Standard
0 0.1 0.2 0.3 0.4 0.5 km
1 : 7100

Sri Lanka is a country that receives sunlight throughout the year. That is, solar power is a sustainable option for a country. Therefore, it is possible to overcome the problems in the energy sector without any doubt. As shown in the above map, there is a large amount of unused land in Hambantota and Wellawaya areas. Moreover, the infrastructure needed to build a new solar power plant is also available in this area. Below is a review of how well solar energy contributes to overcoming the problems in the energy sector.

Energy sources should be diversified. At present, fossil fuels are mostly used to generate electricity. That is, energy generation is heavily dependent on fossil fuels. The price of fossil fuel in the market varies from day to day. Moreover, due to other economic and political reasons, energy security issues arise. Therefore, the energy sources used in the production of electricity should be diversified. A perfect example of this is solar energy.

Facilitating rural electrification. There are many areas in Sri Lanka that are far from normal infrastructure. There are many cases where it is very difficult or expensive to provide electricity to such areas. In such cases, as shown in the map above, solar power plants can be easily generated by building solar power plants on unused vacant land in rural areas with good sunlight.

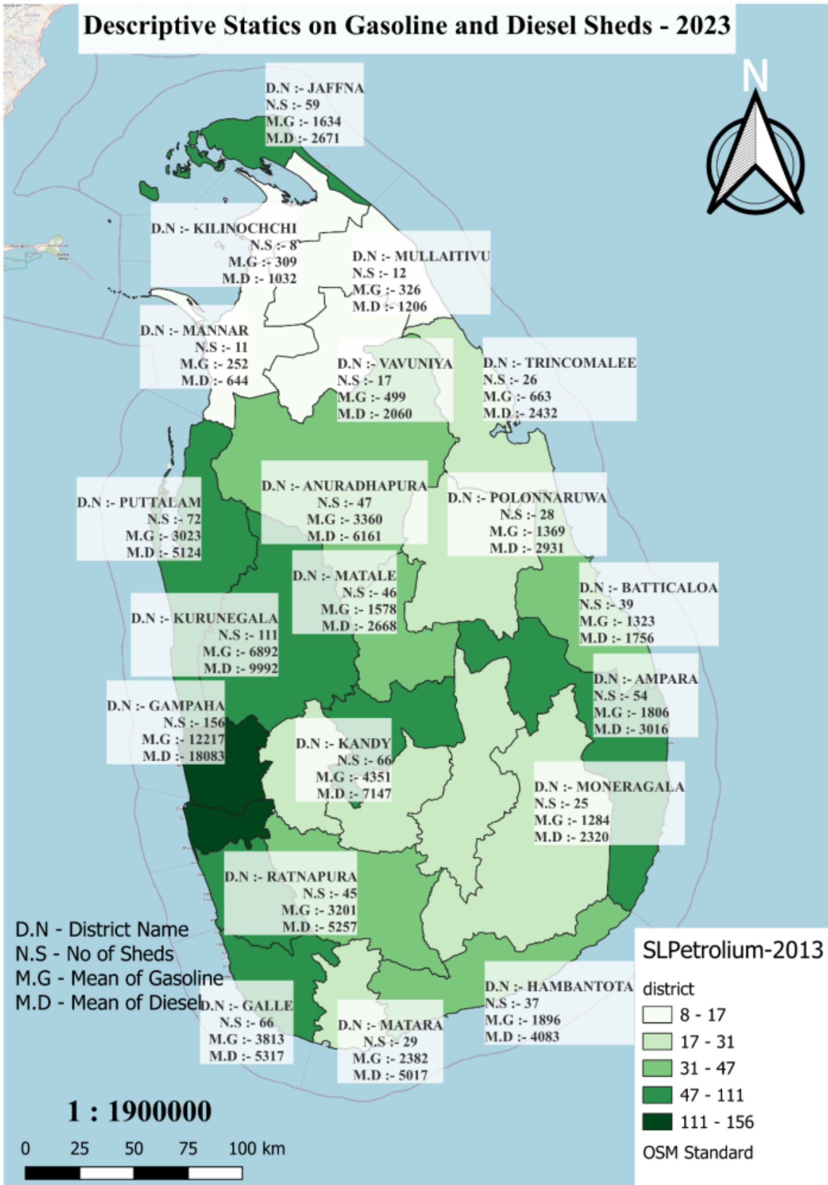
Increased reliability and stability of the network. During periods of drought, the process of generating hydroelectricity stops. During such times, power cannot be provided stably if there is excessive demand. That is, the stability of the grid breaks. In such cases, if there is a solar power plant, it can be matched with the high demand.

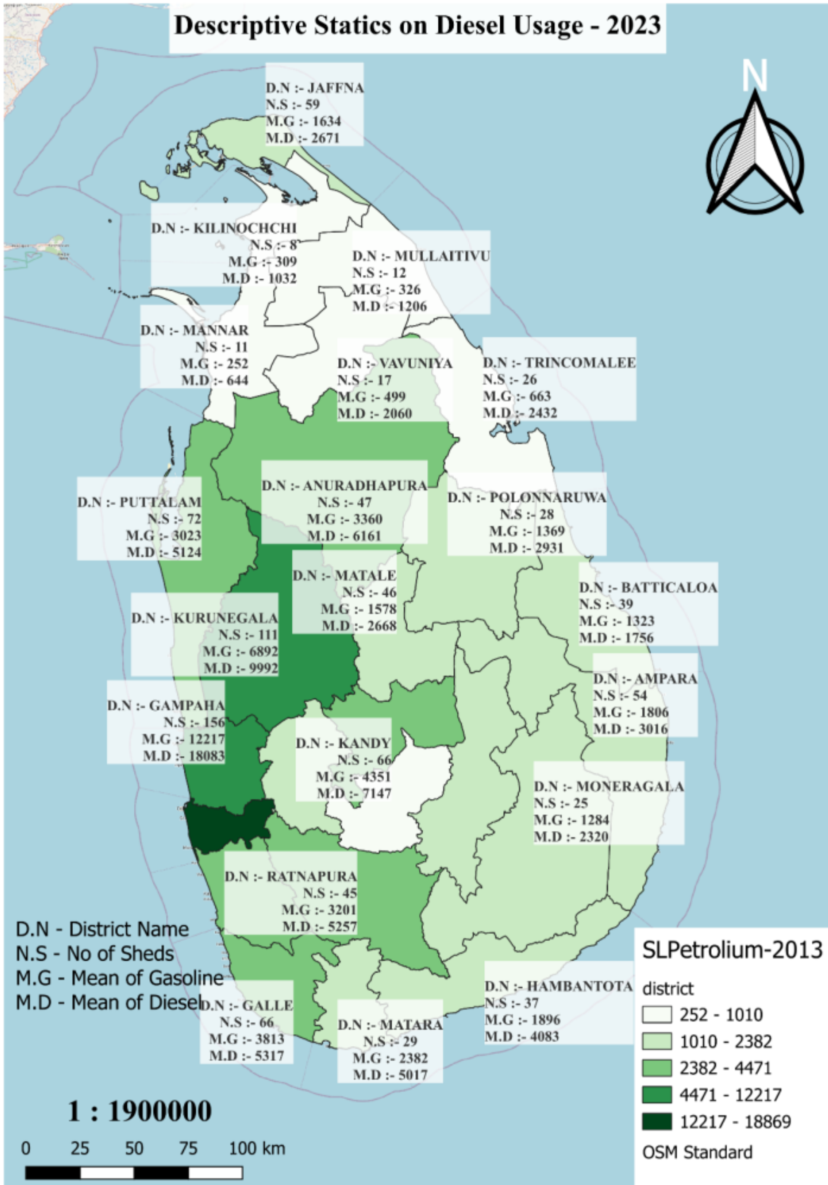
QUESTION F

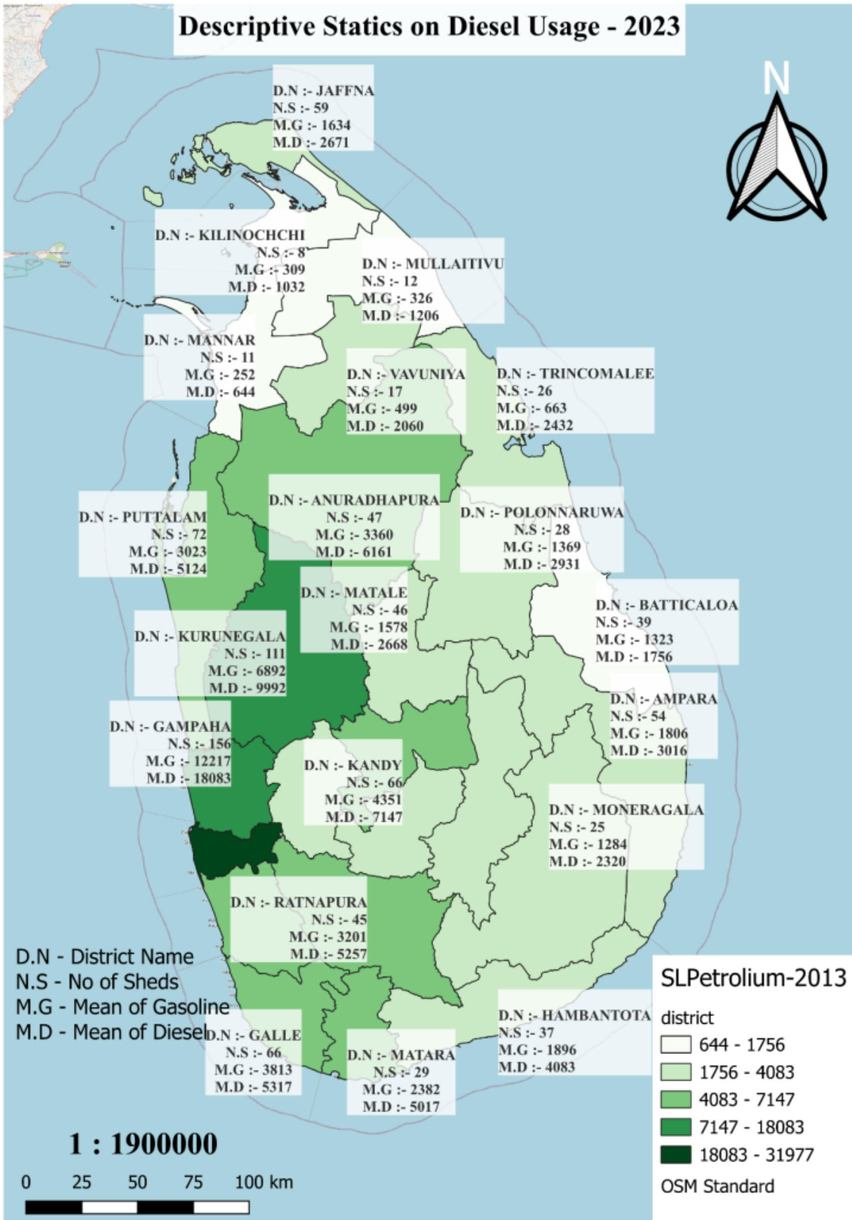
First a PostgreSQL geospatial database is created by entering the provided data. Here, monthly petrol and diesel consumption statistics across districts have been included using data from Sri Lanka Sunitya Energy Authority report. This report has the following topics. They are District Name, Number of Sheds, Petrol Mean and SD, Mean and Diesel SD. Using this data, the distribution of sheds per district is displayed on a map. Below is a screenshot of the afore-mentioned data set.

1	DISTRICT	Number_of_Sheds	Gasoline_SD	Gasoline_Mean	Diesel_SD	Diesel_Mean
2	COLOMBO	151	796	18869	11438	31977
3	GAMPAHA	156	528	12217	4746	18083
4	KALUTARA	56	217	4471	1422	6151
5	KANDY	66	180	4351	2236	7147
6	MATALE	46	81	1578	930	2668
7	NUWARA ELIYA	23	71	1010	1175	2602
8	GALLE	66	185	3813	1317	5317
9	MATARA	29	170	2382	2131	5017
10	HAMBANTOTA	37	112	1896	1690	4083
11	JAFFNA	59	97	1634	826	2671
12	MANNAR	11	23	252	317	644
13	VAVUNIYA	17	37	499	1156	2060
14	MULLAITIVU	12	25	326	688	1206
15	KILINOCHCHI	8	20	309	573	1032
16	BATTICALOA	39	114	1323	660	1756
17	AMPARA	54	118	1806	1080	3016
18	TRINCOMALEE	26	418	663	1169	2432
19	KURUNEGALA	111	303	6892	2684	9992
20	PUTTALAM	72	122	3023	1260	2931
21	ANURADHAPUR	47	183	3360	2199	6161
22	POLONNARUWA	28	404	1369	1260	2931
23	BADULLA	31	115	1808	1343	3495
24	MONERAGALA	25	106	1284	903	2320
25	RATNAPURA	45	169	3201	1706	5257
26	KEGALLE	31	134	2258	922	3378

Below is a thematic map with number of sheds, mean and SD of petrol, mean and SD of diesel for each district using the data set mentioned above.


Descriptive Statics on Gasoline and Diesel Sheds - 2023
D.N :- JAFFNA
N.S :- 59
M.G :- 1634
M.D :- 2671
D.N :- KILINOCHCHI
N.S :- 8
M.G :- 309
M.D :- 1032
D.N :- MULLAITIVU
N.S :- 12
M.G :- 326
M.D :- 1206
D.N :- MANNAR
N.S :- 11
M.G :- 252
M.D :- 644
D.N :- VAVUNIYA
N.S :- 17
M.G :- 499
M.D :- 2060
D.N :- TRINCOMALEE
N.S :- 26
M.G :- 663
M.D :- 2432
D.N :- PUTTALAM
N.S :- 72
M.G :- 3023
M.D :- 5124
D.N :- ANURADHAPURA
N.S :- 47
M.G :- 3360
M.D :- 6161
D.N :- POLONNARUWA
N.S :- 28
M.G :- 1369
M.D :- 2931
D.N :- MATALE
N.S :- 46
M.G :- 1578
M.D :- 2668
D.N :- BATTICALOA
N.S :- 39
M.G :- 1323
M.D :- 1756
D.N :- KURUNEGALA
N.S :- 111
M.G :- 6892
M.D :- 9992
D.N :- AMPARA
N.S :- 54
M.G :- 1806
M.D :- 3016
D.N :- GAMPAHA
N.S :- 156
M.G :- 12217
M.D :- 18083
D.N :- KANDY
N.S :- 66
M.G :- 4351
M.D :- 7147
D.N :- MONERAGALA
N.S :- 25
M.G :- 1284
M.D :- 2320
D.N :- RATNAPURA
N.S :- 45
M.G :- 3201
M.D :- 5257
D.N - District Name
N.S - No of Sheds
M.G - Mean of Gasoline
M.D - Mean of Diesel
D.N :- GALLE
N.S :- 66
M.G :- 3813
M.D :- 5317
D.N :- MATARA
N.S :- 29
M.G :- 2382
M.D :- 5017
D.N :- HAMBANTOTA
N.S :- 37
M.G :- 1896
M.D :- 4083
SLPetrolium-2013
district
8 - 17
17 - 31
31 - 47
47 - 111
111 - 156
OSM Standard
1 : 1900000
0 25 50 75 100 km
N


Descriptive Statics on Diesel Usage - 2023
N
D.N :- JAFFNA
N.S :- 59
M.G :- 1634
M.D :- 2671
D.N :- KILINOCHCHI
N.S :- 8
M.G :- 309
M.D :- 1032
D.N :- MULLAITIVU
N.S :- 12
M.G :- 326
M.D :- 1206
D.N :- MANNAR
N.S :- 11
M.G :- 252
M.D :- 644
D.N :- VAVUNIYA
N.S :- 17
M.G :- 499
M.D :- 2060
D.N :- TRINCOMALEE
N.S :- 26
M.G :- 663
M.D :- 2432
D.N :- ANURADHAPURA
N.S :- 47
M.G :- 3360
M.D :- 6161
D.N :- PUTTALAM
N.S :- 72
M.G :- 3023
M.D :- 5124
D.N :- POLONNARUWA
N.S :- 28
M.G :- 1369
M.D :- 2931
D.N :- MATALE
N.S :- 46
M.G :- 1578
M.D :- 2668
D.N :- BATTICALOA
N.S :- 39
M.G :- 1323
M.D :- 1756
D.N :- KURUNEGALA
N.S :- 111
M.G :- 6892
M.D :- 9992
D.N :- AMPARA
N.S :- 54
M.G :- 1806
M.D :- 3016
D.N :- GAMPAHA
N.S :- 156
M.G :- 12217
M.D :- 18083
D.N :- KANDY
N.S :- 66
M.G :- 4351
M.D :- 7147
D.N :- MONERAGALA
N.S :- 25
M.G :- 1284
M.D :- 2320
D.N :- RATNAPURA
N.S :- 45
M.G :- 3201
M.D :- 5257
D.N - District Name
N.S - No of Sheds
M.G - Mean of Gasoline
M.D - Mean of Diesel
D.N :- GALLE
N.S :- 66
M.G :- 3813
M.D :- 5317
D.N :- MATARA
N.S :- 29
M.G :- 2382
M.D :- 5017
D.N :- HAMBANTOTA
N.S :- 37
M.G :- 1896
M.D :- 4083
SLPetrolium-2013
district
252 - 1010
1010 - 2382
2382 - 4471
4471 - 12217
12217 - 18869
OSM Standard
1 : 1900000
0 25 50 75 100 km

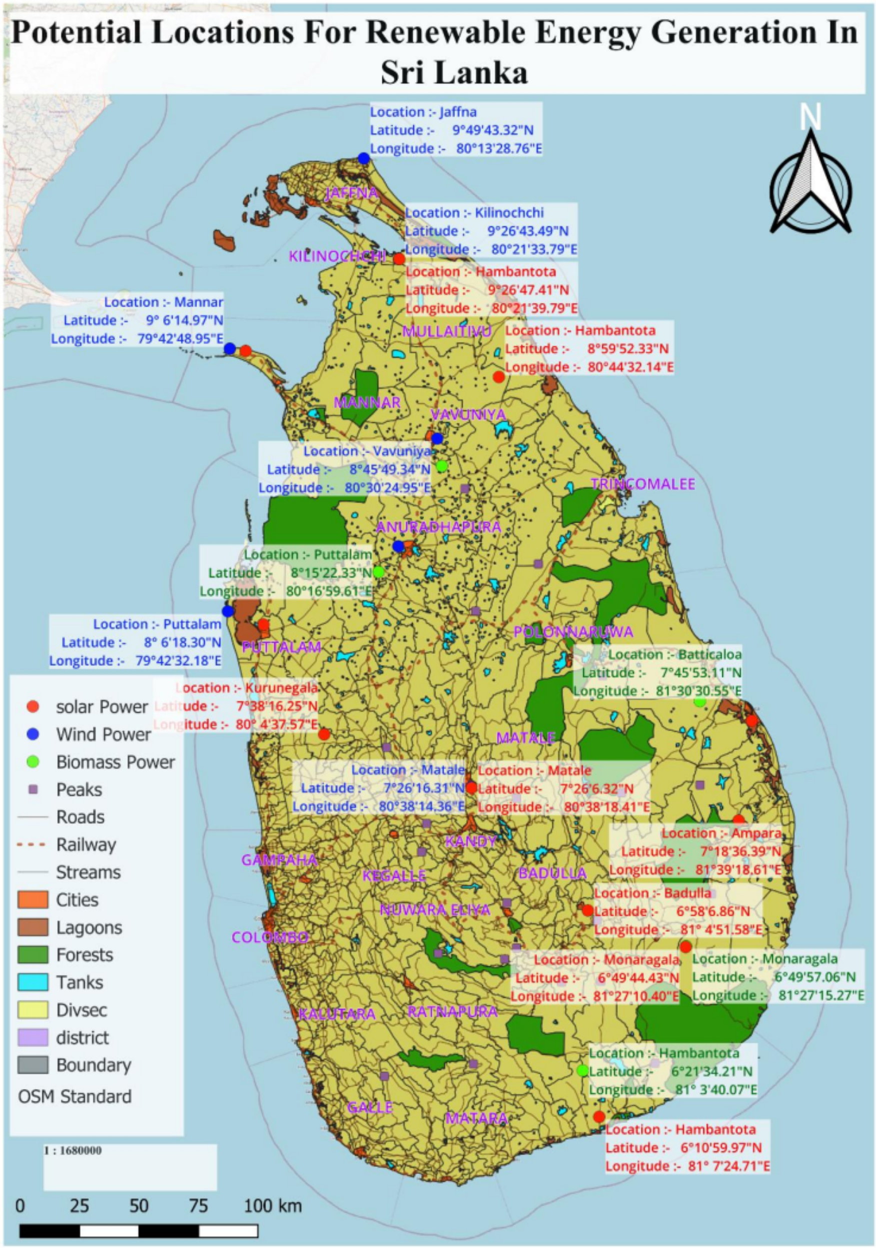

Descriptive Statics on Diesel Usage - 2023
N
D.N :- JAFFNA
N.S :- 59
M.G :- 1634
M.D :- 2671
D.N :- KILINOCHCHI
N.S :- 8
M.G :- 309
M.D :- 1032
D.N :- MULLAITIVU
N.S :- 12
M.G :- 326
M.D :- 1206
D.N :- MANNAR
N.S :- 11
M.G :- 252
M.D :- 644
D.N :- VAVUNIYA
N.S :- 17
M.G :- 499
M.D :- 2060
D.N :- TRINCOMALEE
N.S :- 26
M.G :- 663
M.D :- 2432
D.N :- ANURADHAPURA
N.S :- 47
M.G :- 3360
M.D :- 6161
D.N :- PUTTALAM
N.S :- 72
M.G :- 3023
M.D :- 5124
D.N :- POLONNARUWA
N.S :- 28
M.G :- 1369
M.D :- 2931
D.N :- MATALE
N.S :- 46
M.G :- 1578
M.D :- 2668
D.N :- BATTICALOA
N.S :- 39
M.G :- 1323
M.D :- 1756
D.N :- KURUNEGALA
N.S :- 111
M.G :- 6892
M.D :- 9992
D.N :- AMPARA
N.S :- 54
M.G :- 1806
M.D :- 3016
D.N :- GAMPAHA
N.S :- 156
M.G :- 12217
M.D :- 18083
D.N :- KANDY
N.S :- 66
M.G :- 4351
M.D :- 7147
D.N :- MONERAGALA
N.S :- 25
M.G :- 1284
M.D :- 2320
D.N :- RATNAPURA
N.S :- 45
M.G :- 3201
M.D :- 5257
D.N - District Name
N.S - No of Sheds
M.G - Mean of Gasoline
M.D - Mean of Diesel
D.N :- GALLE
N.S :- 66
M.G :- 3813
M.D :- 5317
D.N :- MATARA
N.S :- 29
M.G :- 2382
M.D :- 5017
D.N :- HAMBANTOTA
N.S :- 37
M.G :- 1896
M.D :- 4083
SLPetrolium-2013
district
644 - 1756
1756 - 4083
4083 - 7147
7147 - 18083
18083 - 31977
OSM Standard
1 : 1900000
0 25 50 75 100 km

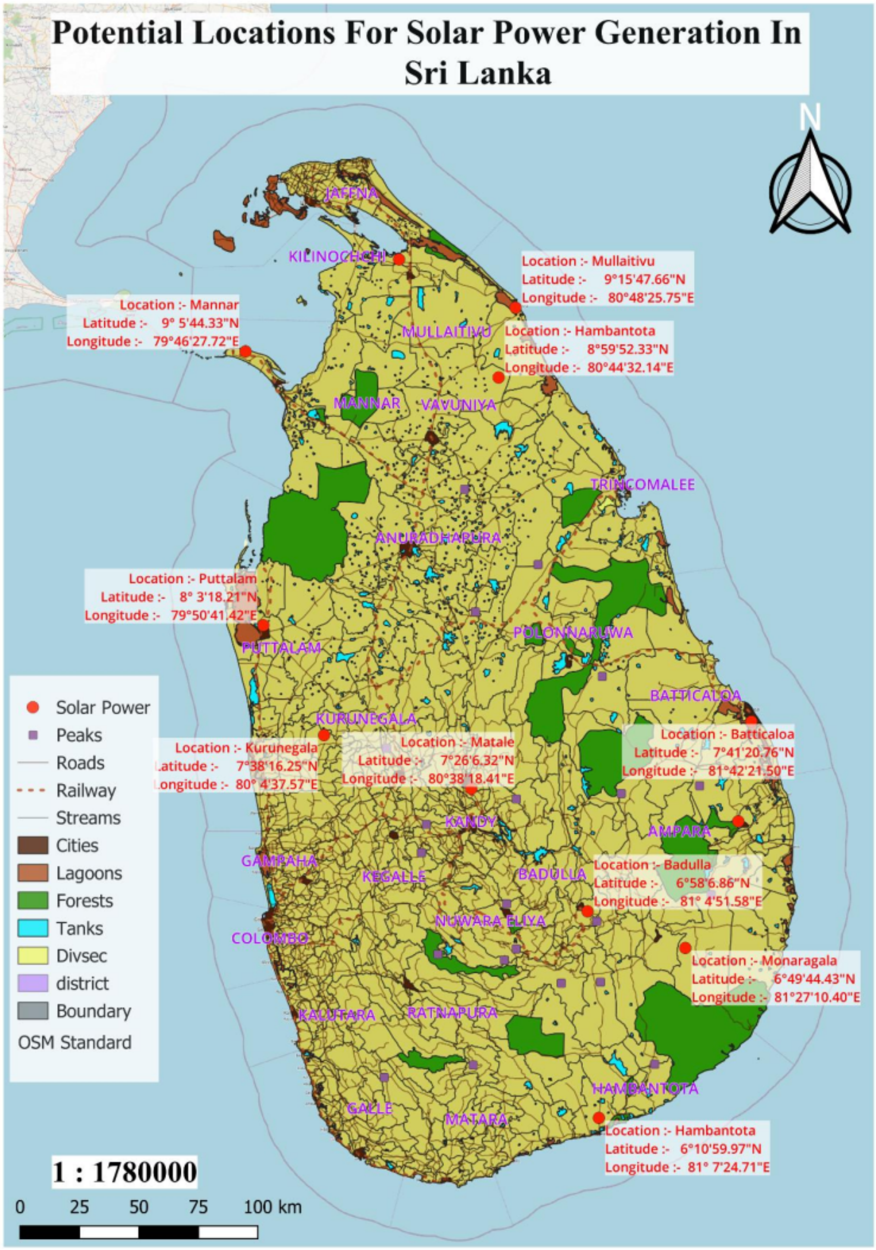
The thematic map shown above displays the number of sheds, mean of petrol and mean of diesel for the districts of Sri Lanka. According to the above map, Gampaha district can be considered as the district with the highest number of sheds in Sri Lanka. The mean value of petrol and diesel consumption in this district is 12217 and 18083 respectively. There are 156 sheds in Gampaha district. But there are only 151 sheds in Colombo district. However, Colombo is the district that consumes the most petrol and diesel in Sri Lanka. It means that a large number of vehicles pass through this district. The construction of new sheds in Colombo district will benefit both the government and the consumer. Thus, the customer can easily get fuel without standing in a queue.

Kurunegala district has the third largest number of sheds in Sri Lanka. In terms of petrol consumption, the third highest petrol consumption in Sri Lanka is in this district. The mean value of petrol and diesel consumption in this district is 6892 and 9992 respectively. Kilinochchi district has the lowest number of sheds in Sri Lanka. That value is 8. However, compared to the districts mentioned above, the use of petrol and diesel is less in the northern area. As the consumption is reduced, it does not matter if the number of sheds is reduced.

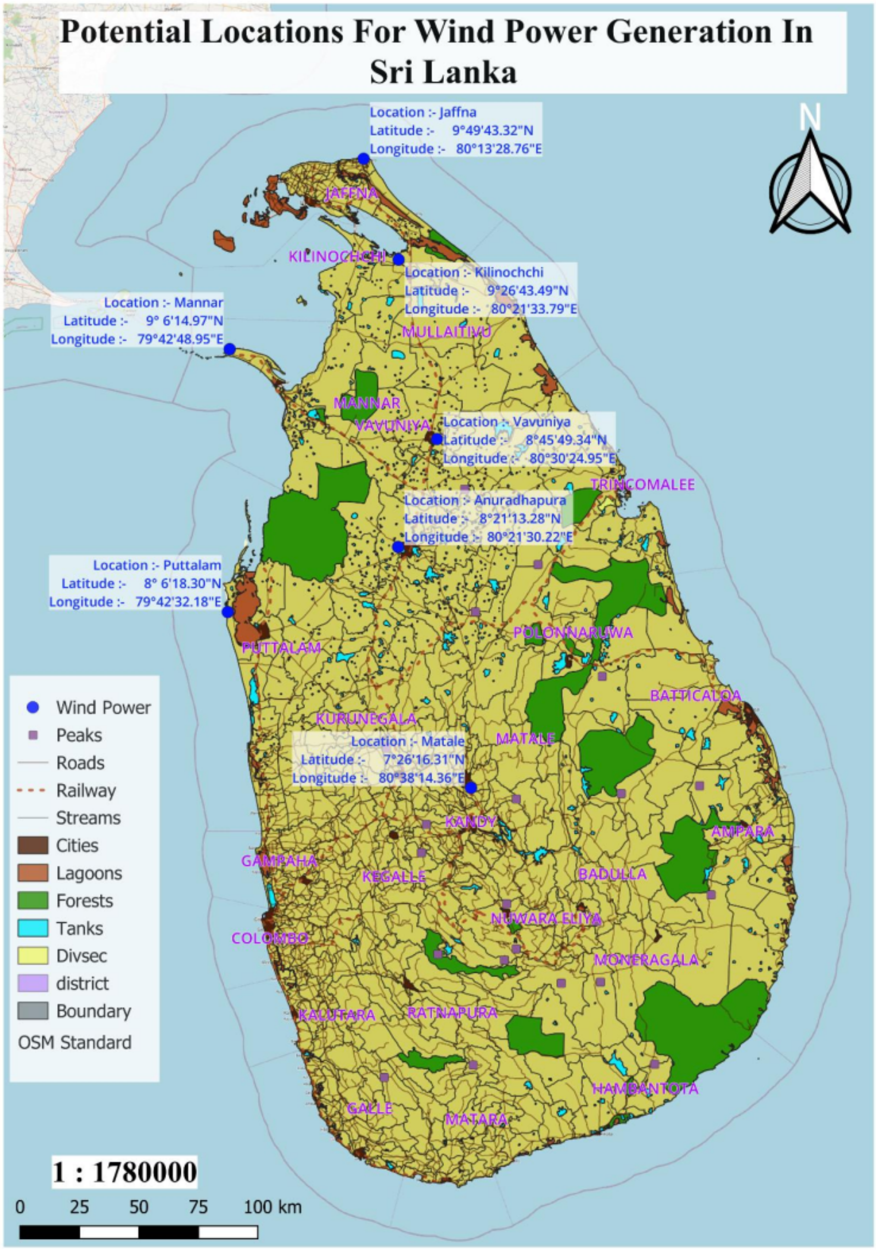
QUESTION G

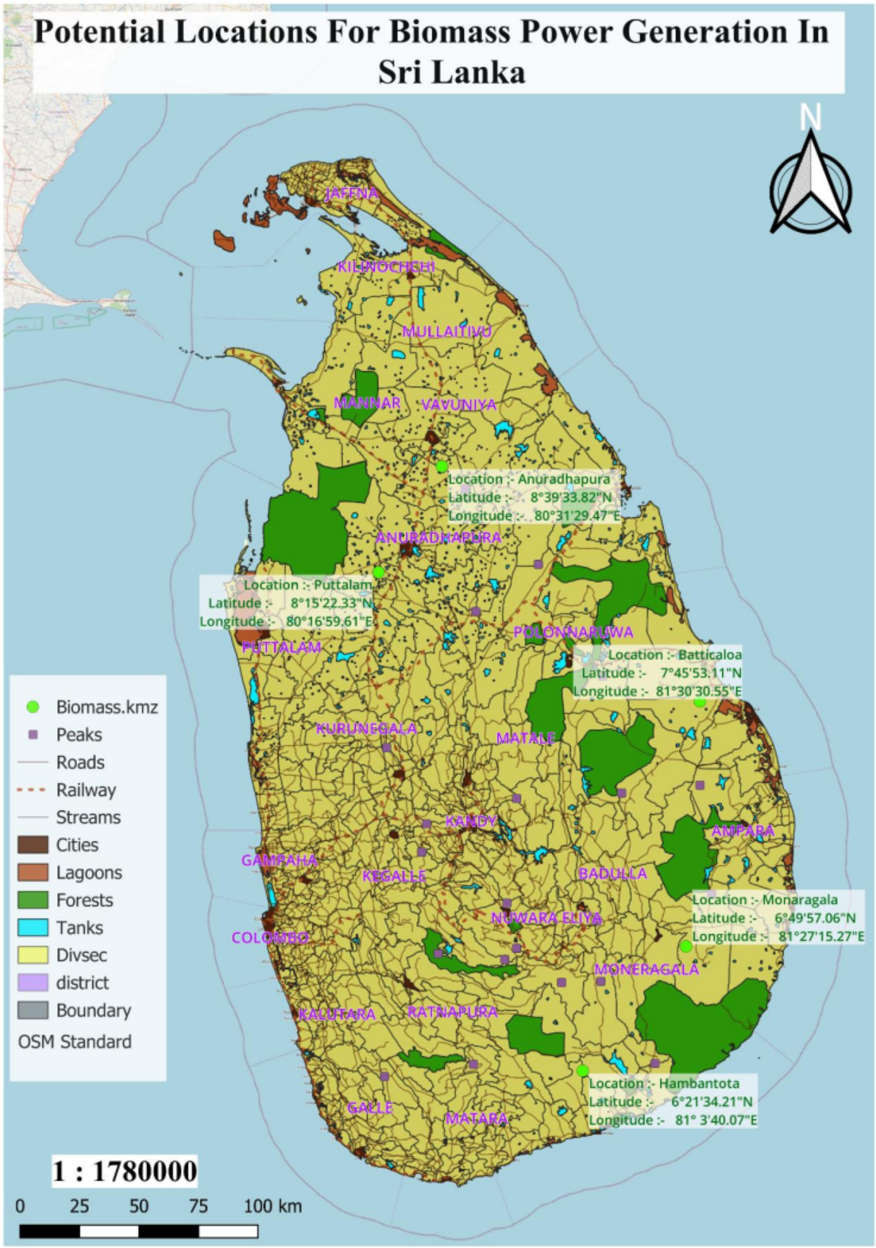
Due to environmental and economic advantages and its importance, all the nations of the world are turning towards renewable energy types in meeting their energy needs. Sri Lanka is a tropical country located in the Indian Ocean and its administrators have focused on using renewable energy sources. SLSEA has identified potential sites for renewable energy generation in Sri Lanka(Rodrigo, n.d.). This chapter deals with the marking of suitable locations on the map for the construction of power plants in the fields of solar, wind and biomass. The suitable locations for construction of power plants are selected and the correct latitude and longitude of the location is obtained by Google Earth Pro, KMZ files are created and the map is created using QGIS. The following map shows the most suitable locations in Sri Lanka for the construction of the above-mentioned power plants.


Potential Locations For Renewable Energy Generation In Sri Lanka
N
Location :- Jaffna
Latitude :- 9°49'43.32"N
Longitude :- 80°13'28.76"E
Location :- Kilinochchi
Latitude :- 9°26'43.49"N
Longitude :- 80°21'33.79"E
Location :- Hambantota
Latitude :- 9°26'47.41"N
Longitude :- 80°21'39.79"E
Location :- Mannar
Latitude :- 9° 6'14.97"N
Longitude :- 79°42'48.95"E
Location :- Hambantota
Latitude :- 8°59'52.33"N
Longitude :- 80°44'32.14"E
Location :- Vavuniya
Latitude :- 8°45'49.34"N
Longitude :- 80°30'24.95"E
Location :- Puttalam
Latitude :- 8°15'22.33"N
Longitude :- 80°16'59.61"E
Location :- Puttalam
Latitude :- 8° 6'18.30"N
Longitude :- 79°42'32.18"E
Location :- Batticaloa
Latitude :- 7°45'53.11"N
Longitude :- 81°30'30.55"E
Location :- Kurunegala
Latitude :- 7°38'16.25"N
Longitude :- 80° 4'37.57"E
Location :- Matale
Latitude :- 7°26'16.31"N
Longitude :- 80°38'14.36"E
Location :- Matale
Latitude :- 7°26'6.32"N
Longitude :- 80°38'18.41"E
Location :- Ampara
Latitude :- 7°18'36.39"N
Longitude :- 81°39'18.61"E
Location :- Badulla
Latitude :- 6°58'6.86"N
Longitude :- 81° 4'51.58"E
Location :- Monaragala
Latitude :- 6°49'44.43"N
Longitude :- 81°27'10.40"E
Location :- Monaragala
Latitude :- 6°49'57.06"N
Longitude :- 81°27'15.27"E
Location :- Hambantota
Latitude :- 6°21'34.21"N
Longitude :- 81° 3'40.07"E
Location :- Hambantota
Latitude :- 6°10'59.97"N
Longitude :- 81° 7'24.71"E
JAFFNA
KILINOCHCHI
MULLAITIVU
MANNAR
VAVUNIYA
TRINCOMALEE
ANURADHAPURA
POLONNARUWA
PUTTALAM
MATALE
KANDY
GAMPAHA
KEGALLE
BADULLA
NUWARA ELIYA
COLOMBO
KALUTARA
RATNAPURA
GALLE
MATARA
solar Power
Wind Power
Biomass Power
Peaks
Roads
Railway
Streams
Cities
Lagoons
Forests
Tanks
Divsec
district
Boundary
OSM Standard
1 : 1680000
0
25
50
75
100 km



Potential Locations For Solar Power Generation In Sri Lanka
N
Location :- Mullaitivu
Latitude :- 9°15'47.66"N
Longitude :- 80°48'25.75"E
Location :- Mannar
Latitude :- 9° 5'44.33"N
Longitude :- 79°46'27.72"E
Location :- Hambantota
Latitude :- 8°59'52.33"N
Longitude :- 80°44'32.14"E
Location :- Puttalam
Latitude :- 8° 3'18.21"N
Longitude :- 79°50'41.42"E
Location :- Kurunegala
Latitude :- 7°38'16.25"N
Longitude :- 80° 4'37.57"E
Location :- Matale
Latitude :- 7°26'6.32"N
Longitude :- 80°38'18.41"E
Location :- Batticaloa
Latitude :- 7°41'20.76"N
Longitude :- 81°42'21.50"E
Location :- Badulla
Latitude :- 6°58'6.86"N
Longitude :- 81° 4'51.58"E
Location :- Monaragala
Latitude :- 6°49'44.43"N
Longitude :- 81°27'10.40"E
Location :- Hambantota
Latitude :- 6°10'59.97"N
Longitude :- 81° 7'24.71"E
JAFFNA
KILINOCHCHI
MULLAITIVU
MANNAR
VAVUNIYA
TRINCOMALEE
ANURADHAPURA
POLONNARUWA
PUTTALAM
BATTICALOA
KURUNEGALA
MATALE
KANDY
AMPARA
GAMPAHA
KEGALLE
BADULLA
NUWARA ELIYA
COLOMBO
KALUTARA
RATNAPURA
HAMBANTOTA
GALLE
MATARA
Solar Power
Peaks
Roads
Railway
Streams
Cities
Lagoons
Forests
Tanks
Divsec
district
Boundary
OSM Standard
1 : 1780000
0 25 50 75 100 km


Potential Locations For Wind Power Generation In Sri Lanka
Location :- Jaffna
Latitude :- 9°49'43.32"N
Longitude :- 80°13'28.76"E
Location :- Kilinochchi
Latitude :- 9°26'43.49"N
Longitude :- 80°21'33.79"E
Location :- Mannar
Latitude :- 9° 6'14.97"N
Longitude :- 79°42'48.95"E
Location :- Vavuniya
Latitude :- 8°45'49.34"N
Longitude :- 80°30'24.95"E
Location :- Anuradhapura
Latitude :- 8°21'13.28"N
Longitude :- 80°21'30.22"E
Location :- Puttalam
Latitude :- 8° 6'18.30"N
Longitude :- 79°42'32.18"E
Location :- Matale
Latitude :- 7°26'16.31"N
Longitude :- 80°38'14.36"E
JAFFNA
KILINOCHCHI
MULLAITIVU
MANNAR
VAVUNIYA
TRINCOMALEE
PUTTALAM
POLONNARUWA
BATTICALOA
KURUNEGALA
MATALE
KANDY
AMPARA
GAMPAHA
KEGALLE
BADULLA
NUWARA ELIYA
COLOMBO
MONERAGALA
KALUTARA
RATNAPURA
HAMBANTOTA
GALLE
MATARA
Wind Power
Peaks
Roads
Railway
Streams
Cities
Lagoons
Forests
Tanks
Divsec
district
Boundary
OSM Standard
1 : 1780000
0 25 50 75 100 km
N


Potential Locations For Biomass Power Generation In Sri Lanka
N
JAFFNA
KILINOCHCHI
MULLAITIVU
MANNAR
VAVUNIYA
Location :- Anuradhapura
Latitude :- 8°39'33.82"N
Longitude :- 80°31'29.47"E
ANURADHAPURA
Location :- Puttalam
Latitude :- 8°15'22.33"N
Longitude :- 80°16'59.61"E
POLONNARUWA
PUTTALAM
Location :- Batticaloa
Latitude :- 7°45'53.11"N
Longitude :- 81°30'30.55"E
Biomass.kmz
Peaks
Roads
Railway
Streams
Cities
Lagoons
Forests
Tanks
Divsec
district
Boundary
OSM Standard
KURUNEGALA
MATALE
KANDY
AMPARA
GAMPAHA
KEGALLE
BADULLA
Location :- Monaragala
Latitude :- 6°49'57.06"N
Longitude :- 81°27'15.27"E
NUWARA ELIYA
COLOMBO
MONERAGALA
KALUTARA
RATNAPURA
Location :- Hambantota
Latitude :- 6°21'34.21"N
Longitude :- 81° 3'40.07"E
GALLE
MATARA
1 : 1780000
0 25 50 75 100 km

In the above map, the 3 types of power plants are marked with three colors. Red indicates solar power plants and blue indicates wind power plants. Biomass plant is shown in green. Forests, rivers, reservoirs are also included in the map.

There are many points to be aware of while scoring the above positions. First, research should be done in finding suitable locations for solar power plants. According to the data provided by Sri Lanka Solar Energy Authority, they have specified many possible locations and we have selected the most suitable locations among them. The locations suitable for setting up solar power plants in the selected districts are marked in red. 12 districts like Ampara, Mullaitivu, Mannar, Kurunegala, Batticaloa, Badulla etc. have been selected to build solar power plants. The latitude and longitude of the selected location in that respective district is visualized on the map.

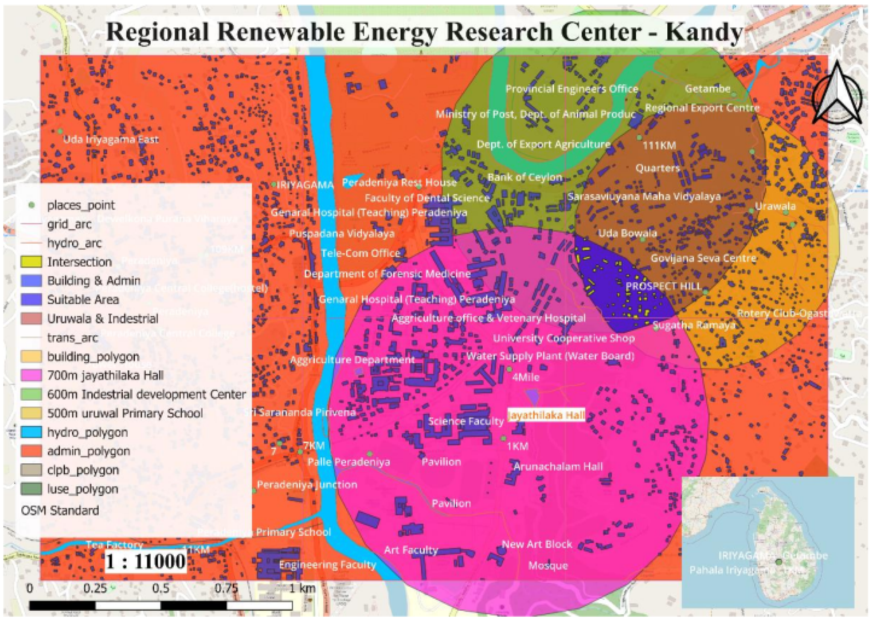
7 locations in 7 districts have been selected for the construction of wind power plants. They are Anuradhapura, Jaffna, Kilinochchi, Mannar, Matale, Puttalam and Vavuniya. While marking these places, schools, hospitals and homes were chosen. As mentioned in the above section, the latitude and longitude are also shown in these places.

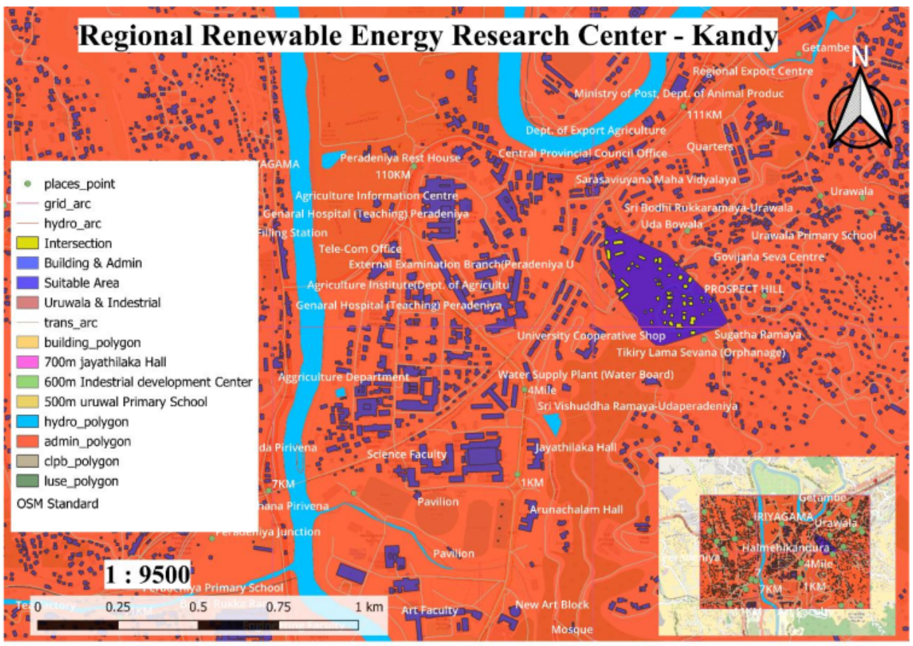
For the construction of biomass power plants in the districts of Hambantota, Monaragala, Anuradhapura, Batticaloa and Puttalam, the green areas are marked.

According to the above map, the power authority can start the construction of power plants very easily.

QUESTION H

In this chapter, a map is created to find a suitable land in Kandy to build a regional research center on renewable energy. Three areas of vegetation are used to find the most suitable land. They are Industrial Development Centre, Uruvala Primary School and Jayathilaka Hall. This land should be sought from a certain distance to these places (500 meters from Uruvala Primary School, 600 meters from Industrial Development and 700 meters from Jayathilaka Hall).





Regional Renewable Energy Research Center - Kandy
places_point
grid_arc
hydro_arc
Intersection
Building & Admin
Suitable Area
Uruwala & Indestrial
trans_arc
building_polygon
700m jayathilaka Hall
600m Indestrial development Center
500m uruwal Primary School
hydro_polygon
admin_polygon
clpb_polygon
luse_polygon
OSM Standard
1 : 9500
0 0.25 0.5 0.75 1 km
N

Suitable Area for Research center In Kandy	
Total number of buildings situated within the suitability area at present.	55
Total land area occupied by the buildings within the suitability area.	$73421m^2$
Total suitable land area	$7928.76m^2$

Stations are used to carry out the various station planning process as mentioned in the figure above. Accordingly, 03 locations have been used for planning the intersection, Uruwela Primary School, Industrial Development Center and Jayathilaka Hall. As indicated by each color, the yellow circle on the map is five hundred meters from Uruwela Vidyalaya, the green circle is 600 meters from the Task Development Center and the pink is 700 meters from Jayathilaka Hall. The best area for fishing is shown in blue. It should be said that the Agricultural Service Center is located around the selected area. Also, Sugatharamaya is located on the right. There are 55 buildings in the area reserved for the above-mentioned regional research centers.

Finally, the regional research center created for this renewable energy will provide several opportunities such as regional innovation, educational development and sustainable development.

55 buildings were identified in the allotted area to find suitable land for the construction of the Regional Research Centre. The total area of this entire area is $73421m^2$. But the area of land suitable for building the building in this area is about $7928.76m^2$.

CONCLUSION

In the first and second tasks, accurate statistical models were created based on the structural factors and cooling factors of a building using the R programming language and the aforementioned data set and data analysis were performed. At the end of this analysis, the relationships between cooling systems, building structures and energy consumption were identified. They are described separately.

In the third task, using the dataset "SLWindPowerLand_21_23.csv", a visual representation of the feasible land for the construction of new wind farms in Sri Lanka has been made. Here the viable land available in each district is shown on the map.

In the fourth task, a classified map is created based on the estimated total energy generation of the land district suitable for the construction of solar power plants using the given data as done in the third task above.

In the fifth task, information about solar power plants and buildings on the Google Earth aerial image map was digitized using QGIS.

In the sixth task, a database was created in the PostgreSQL application using statistical data including monthly petrol and diesel consumption. A classification map was then created based on that data.

In the seventh task, suitable locations for renewable energy generation in Sri Lanka were identified using Google Earth and mapped using QGIS.

In the final task, a suitable land was selected for the construction of a regional research center in Kandy using QGIS and a map was created containing information about the area and the area.

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