External Factor Prediction of Dengue Fever Spread in Surabaya using Geospatial Weighted Regression

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Abstract: Surabaya is the second largest city in Indonesia with high density population which can cause many living problem such as dengue fever. Dengue fever outbreak is caused by *Aedes aegepty* and spread fast in high density population. Many researches about dengue fever had been done in other city and country in order to decrease the spread of this outbreak. This research's aim is to predict external factor that can caused dengue fever outbreak in Surabaya. Method that is used in this paper is Geospatial Weighted Regression (GWR) which focus on local coefficient estimates at each health centres in Surabaya. Health centres that have high local coefficient estimates have strong correlation of spreading dengue fever in Surabaya. This research's only focused 3 external factor in which consist of family poverty percentage, precipitation, and levels of education. Levels of education is the only factor that have high local coefficient estimates and have strong correlation of spreading dengue fever in Surabaya compared to the other factors.

Keywords: dengue fever; geospatial weighted regression; local coefficient estimates; clustering; local moran I statistics; global moran I statistics.

Introduction

Surabaya is the second largest city in Indonesia and also the capital of East Java province. Surabaya have 3.1 million inhabitants with an area of 310.15 km^2. Population density of Surabaya is 14,120 inhabitants/ km^2. Surabaya's population density quite high due to Surabaya is a big city with high growth of economic and are characterized by industrial and education development. High population density can caused many living problem such as the increase of unemployment, criminality and also health problems. One of the health problems is dengue fever (Statistic Bereau Kota Surabaya [1]). Dengue fever outbreak happening most likely at tropical countries such as Indonesia and spread easily in areas with high population density and high humidity. Dengue fever cause by *Aedes aegepty* mosquito and have peak of spread in December to February (WHO [2]). In 2018, there is 3,686 dengue fever cases in East Java Province and 55 victims are died because of this outbreak. This number of cases in East Java Province is the highest in Indonesia (Baihaqi [3]). In Surabaya, there are 322 cases of dengue fever and that number is decreased from 2017 cases (325 cases).

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Therefore, predicting the dengue fever outbreak has become the subject of researches of many tropical countries. Some of those researches predicted the external factor of dengue fever such as in Sri Lanka with Geographycally Weighted Regression method using population density and precipitation as the external factor and the result was 56,3% of dengue fever cases in Sri Lanka caused by population density and precipitation factor (Sumanasinghe *et al.* [4]). Other research conducted in Karawang and the purpose of the research was to find out the relationship between levels of education and people's knowledge regarding prevention of dengue fever. The result of the research explained that levels of education influence people's knowledge about the prevention of dengue fever. People with only graduated from elementary school have the fewest knowledge about the prevention of dengue fever (Putri *et al.* [5]).

Past research to predict dengue fever spreading in Surabaya has been focused on the effect of population density and poverty percentage using Geographycally Weighted Regression. The result was population density and poverty percentage have influenced of dengue fever spreading in Surabaya but the result can't predict accurately because of the model's Mean Square Error (MSE) was high (Halim *et al.* [6]). The goal of this research is to predict the external factors that have impact on spreading dengue fever in

Surabaya. Those external factor that used in this research is levels of education, family poverty percentage and precipitation. Those external factor were choosen due to past research that held in other city and country which have high impact on dengue fever spreading. Geospatial Weighted Regression is used in this research bcause of this model allows the estimated parameter vary locally so we can know which health centres is influenced with the ecxternal factor (Dziauddin *et al.* [7]).

Methods

In this secment, all of the methods that used in this research will be discussed. The first step that we did was analyzed descriptive data.

Descriptive Analysis

The first step in descriptive analysis is summarizing all the data we have and the clustered it based on the location of the health centres. The data that used in clustering were levels of education (graduate from elementary school, junior high school and senior high school), family poverty percentage, and precipitation. In clustering, we used K-Medoids algorithm instead of K-Means algorithm because of K-Medois's algorithm more robust to the outlier and also if we from time to time, the results of K-Medoids never change (the results were always the same). In K-Medoids clustering, each cluster is represented by one of the data points in the cluster which are called cluster medoids. The most common method of K-Medoids clustering is Partioning Around Medoids (PAM). The first step of this method is select the k object to become medois and the calculate the dissimilarity matrix. The next step is to find the number of cluster using PAM where the method that used in PAM is silhouette. The selection of the number of cluster seen from the biggest number of average silhouette width from each external factors. The next step is run the K-Medoids clustering to get the results of the clustering (Kassambara [8]).

Geospatial Weighted Regression (GWR)

There are many model that were used in the past research especially about external factor that caused dengue fever. In this research, we used Geospatial Weighted Regression. At first, we tested spatial global autocorrelation using global Moran's I statistic. The null hypothesis of the test is theobserved random variable is randomly distributed (Lu *et al.* [9]). The global Moran's I statistics can be formulated as :

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_{i=1}^{n}(X_i - \bar{X})^2} \quad (1)$$

Equation (1) is used to calculate the global Moran's I statistics where x is the observation data and $\bar{x}$ is the mean of observation data. w_{ij} is the weight for the i, j observation and formulated as the Gaussian function:

$$W_{ij} = e^{(\frac{D_{ij}}{b})^2} \quad (2)$$

where dij is the eucledian distance between the location of observation i and location j, while b is the kernel bandwith. Bandwith is the key to control the parameter and can be specified as fixed distance (Lu *et al.* [9]). We also test the local Moran's I statistics to identify the local clusters and local spatial outliers. Many researches have applied the local Moran's I test in their research such as (Halim *et al.* [10]) and can be formulated as :

$$I = \frac{n(Y_i - \bar{Y})\sum_{j=1}^{n} W_{ij}(Y_i - \bar{Y})}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2} \quad (3)$$

where y is the variable of interest. This research's model can be estimated as :

$$Y_i = X\beta + \varepsilon_i \quad (4)$$

where X are the external factors of this research (independent variables), Y is the number of dengue fever cases in each location, εi is the random error in each location and βi is the parameters at the location I and can be estimated as:

$$\beta i = (X^T W_i X)^{-1} X^T W_i Y \quad (5)$$

Results and Discussions

The data were collected from all of the community health centres (Pusat Kesehatan Masyarakat) and there were 63 community health centres in Surabaya. Community health centres are provided by government for the population on sub-district level (Kelurahan). In Surabaya, each community centres provide from one to three sub-district level (Permenkes [11]). From 2016 to 2018, the most dengue fever cases was happen in 2016 with 938 cases.

The cases decreased in 2017 (325 cases) and 2018 (322 cases) because of the prevention efforts made by all inhabitants of Surabaya and also the Government of Surabaya has a program called "Ibu Pemberantas Jentik Nyamuk (BUMANTIK)" (Setyorini [12]). In this paper, we will study the external factors that can have impact on spreading of dengue fever in Surabaya. This research will help the Government of Surabaya to prevent dengue fever in the future so the number of the cases decreased. We collected data of population, area, population desnity, total of family, family poverty percentage, precipitation, humidity, max and min temperatures, levels of education for each district (Kecamatan) in Surabaya.

Table 1. Surabaya's district statistics in 2018 (BPS [13])

Category	Min	Mean	Max
Population (thousand)	13,617	49,247	94,440
Area (km^2)	0.39	4.49	17.59
Density (thousand/km^2)	1,618	21,743	141,407
Total Family	4,127	14,659	29,055
Family Poverty (%)	3.32	16.15	45.99
Precipitation (mm/month)	174.72	482.97	530.38
Humidity (%)	70	73.38	80
Max Temperatue (°C)	33.90	34.98	35.67
Min Temperatue (°C)	22.24	23.18	25.23
E. School Gradute (%)	1.09	17.12	35.96
J.H. School Graduate (%)	5.17	12.83	38.54
S.H. School Graduate (%)	10.25	26.41	37.82

Clustering

The next step to cluster all the external factors with dengue fever incidence. First, we assume that there is a relationship between levels of education with dengue fever incidence (DFI) or dengue fever rate (DFR). DFR can be calculated as (Spronk *et al.* [14]) :

$$DFR_i(t) = \frac{\#DFI_i(t)}{\#population_i(t)} \ x\ 10{,}000 \qquad (6)$$

where i is the location of the health centres. Before clustrering the levels of education with DFR and DFI, we first test using ANOVA to know if there is any mean different between elementary school graduate, senior high school graduate and senior high school graduate. The result is p-value (0.000) < α (0.05) so there is no mean difference and we choose to use elementary school and senior high school graduates data in the analysis because that two factor have the higher mean instead of junior high school graduate. (see Table 2). Optimal number of cluster is choose based on the highest number of average silhouette width. Based on the highest number of average silhouette, we get that the optimal number for cluster is two (see Figure 1).

Table 2. ANOVA test for levels of education

Factor	N	Mean	StDev	95%CI
% E. School	63	17.125	7.585	(15.582, 18.668)
% J.H. School	63	12.835	4.058	(11.292, 14.378)
% S.H. School	63	26.416	6.450	(24.873, 27.959)

Then, we used the K-Medoids clustering and the optimum number of cluster (two clusters) to cluster the regions with levels of education (elementary school graduates, junior high school graduates and senior high school graduates), DFR and DFI. The result that we can see on Figure 2 where we get Surabaya map that already been clustered with level of education, DFR and DFI.

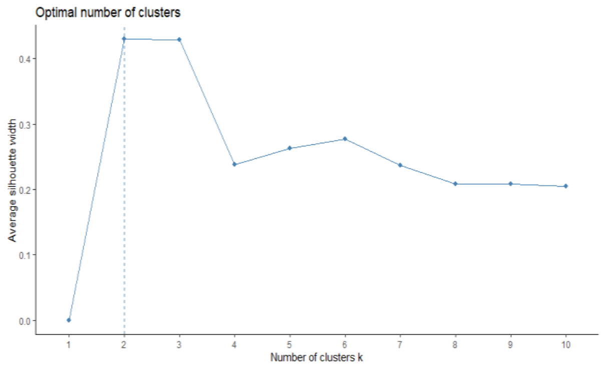

Figure 1. Optimum number of levels of education's cluster

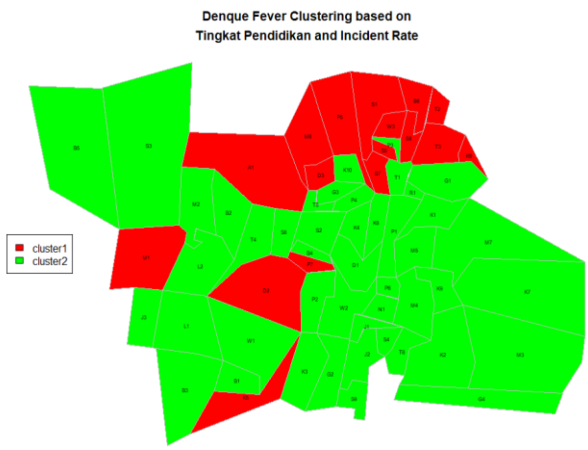

Figure 2. Map of Surabaya based on clustering levels of education, DFR and DFI

Table 3. Cluster summary for mean of levels of education to mean of DFR and DFI

Cluster	% E. School	% J.H. School	% S.H. School	DFR 2018	DFI 2018
Cluster 1	26.98	13.36	19.81	1.50	6.68
Cluster 2	13.48	12.63	25.85	0.91	4.54
T-Test (p-value)					0.065

The next step after clustering is we do T-Test to prove that levels of education have influence or not on spreading dengue fever in Surabaya. The result shows that p-value (0.065) > α (0.05) so levels of education have influence on spreading dengue fever in Surabaya (see Table 3). From the results of the clustering, we also can see that on cluster 1 the percentage of elementary school graduate (26.98) is higher than the percentage of senior high school (19.81) graduate and it's followed by higher number DFR (1.50) and DFI (6.68) than cluster 2 that have higher levels of education (senior high school graduate (25.85%) > elementary school graduate (13.48%)). Putat Jaya has the highest number of cases in Surabaya in 2018 with 17 cases. Putat Jaya is on cluster 1 which has lower level of education. This location have 48,311 population so the DFR is 3.51. Other location that have higher number of dengue fever cases is Medokan Ayu. Medokan Ayu has 16 cases of dengue fever but this location wasn't on cluster 1. This location have high dengue fever cases because the location of the sub-district level near the sea and many swamp (see Figure 3). The area that bordering to the sea and swamps have many small puddle that can cause *Aedes aegepty* mosquito grow faster and effecitively (Ariati *et al.* [15]).

Figure 3. Map of Medokan Ayu sub-dictrict level

Secondly, we assume that family poverty percentage influence DFR and DFI. Using similar approach as level of education, we got also two clusters (see Figure 4) and the summary of the clusters given in Table 4. The result that we can see on Figure 5 where we get Surabaya map that already been clustered with family poverty percentage, DFR and DFI.

Table 4. Cluster summary for mean of family poverty percentage to mean of DFR and DFI

Cluster	Family Poverty (%)	DFR 2018	DFI 2018
Cluster 1	30.72	0.92	4.85
Cluster 2	11.99	1.11	5.16
T-Test (p-value)			0.000

Using T-Test, we want to verify if family poverty percentage have influence on spreading dengue fever

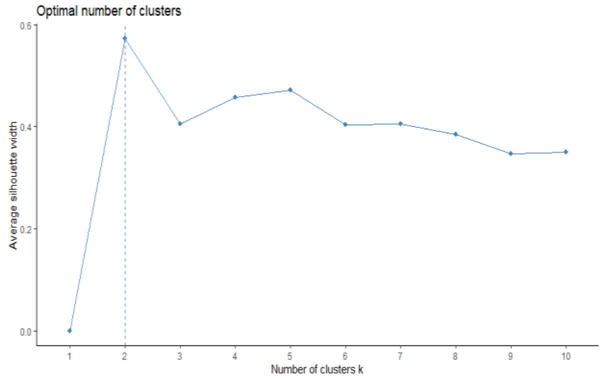

Figure 4. Optimal number of family poverty percentage's cluster

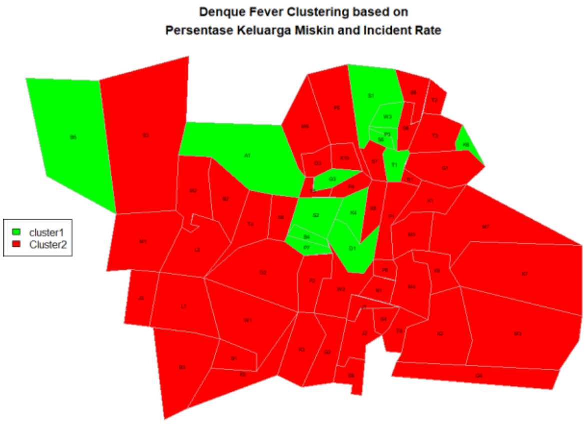

Figure 5. Map of Surabaya based on clustering family poverty percentage, DFR and DFI

in Surabaya. Cluster 1 have high percentage of family poverty (30.72%) but low DFR (0.92) and DFI (4.85). Otherwise, cluster 2 have low percentage of family poverty (11.99%) but higher DFR (1.11) and DFI (5.16) that cluster 1. From this results, we conclude that family poverty percentage not influenced on spreading dengue fever in Surabaya and it's followed by T-Test result where the p-value of the test (0.000) < α (0.05). Lastly, we assume that precipitation influence DFR and DFI. The precipitation data divided into 5 clusters. The results was given in Table 5.

Table 5. Cluster summarty for mean of precipitation to mean of DFR and DFI

Cluster	Precipitation	DFR 2018	DFI 2018
Cluster 1	439.75	0.4	2
Cluster 2	486.86	1.08	5.31
Cluster 3	370.58	0.81	4.6
Cluster 4	524.53	1.10	4.94
Cluster 5	175.28	1.22	7.33
ANOVA (p-value)			0.000

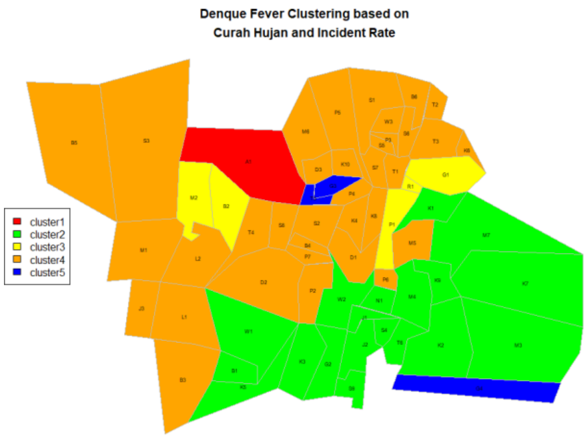

Figure 6. Map of Surabaya based on clustering precipitation, DFR and DFI

The result that we can see on Figure 6 where we get Surabaya map that already been clustered with precipitation, DFR and DFI. Using one-way Analysis of Variance (ANOVA), we test if precipitation have influence on spreading dengue fever in Surabaya. Our hypothesis is the larger precipitation lvele have higher DFR and DFI but the results show that the lowest precipitation level have the highest DFR and DFI. The ANOVA test also shows that the p-value (0.000) > α (0.05) and we can conclude that precipitation not influence on spreading dengue fever. However, we did further research because we weren't satisfied with the results. Surprisingly, we found out that instead of higher level of precipitation, the lower level of precipitation have higher chance on spreading dengue fever. That's because on the lower precipitation level can form a lot of small water reservoirs. Small water reservoir are the best spot for *Aedes aegepty* mosquito to grow effectively (Koesnayani *et al.* [16]). The regions which are registered in cluster 3 are Tembok Dukuh, Gunung Anyar and Gundih. Those regions have an average of precipitation 175.28 mm/year. Among those 3 regions, Tembok Dukuh have the highest DFR (2.1 with DFI 13), which followed by Gunung Anyar (DFR 1.36 with DFI 8) and Gundih (DFR 0.22 with DFI 1).

Global Linier and Spatial Model

The summary statistics and the clustering above give us clear description of the dengue fever rate and the number of infected person that happened in Surabaya. In this section, we will explore more about global and local parameters to predict the DFR and the factors that influenced in every community health centres in Surabaya.

The first step is to do the global Moran's I statistics to test if the data are under randomization or have spatial dependencies (H_0). The result of the test shows that p-value (0.2002) > α (0.05) and that means all of the community health centres in Surabaya are independent and don't have spatial dependencies (see Figure 7).

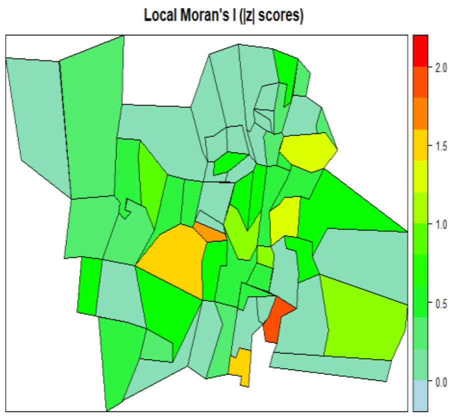

Figure 7. Local moran's I statistic

At first, we used the simple linear regression to predict the external factor that may influenced DFR. We regressed the DBR2018 to the family poverty percentage, precipitation, levels of education, DFR 2013, DFR 2014, DFR 2015, DFR 2016 and DFR 2017. The results of the regression shows that only levels of education parameter is significant on predicting DFR 2018 where other parameters are not really significant since the results is so low. The model is also not really good because of the adjuster R^2 only 30.16%. Full results of the regression can be seen on Table 6.

Table 6. Statistics summary for global model using linier regression and spatial models

Model	LM	SAR	SEM	SDM
Intercept	-0.1767	-0.0902	-0.1475	-0.0902
Family Poverty	0.0039	0.0038	0.0035	0.0038
Precipitation	-0.0010	-0.0010	-0.0010	-0.0010
Levels fof Edu.	18.645	18.470	18.448	18.470
DFR2013	0.0963	0.0958	0.0965	0.0958
DFR2014	0.0797	0.0827	0.0786	0.0827
DFR2015	-0.0311	-0.0338	-0.0323	-0.0338
DFR2016	0.0031	0.0033	0.0031	0.0033
DFR2017	0.4078	0.4119	0.4073	0.4119
R^2	0.3016			
AIC		156.90	157.04	156.90

where LM is Linier Model, SAR is Spatial Auto Regressive, SEM is Spatial Error Model, and SDM is Spatial Durbin Model.

To improve the model performance, we then use the Geospatial Weighted Regression to model the find the external factor that influenced on spreading dengue fever in Surabaya.

Geospatial Weighted Regression (GWR)

Geospatial Weighted Regression models can show the parameters locally to estimate which external factors have influenced on spreading dengen fever in each community health centres. The results of the GWR local coefficient estimates in every community health centres can be seen in Table 7.

Table 7. Summary of local coefficient estimates

	Global	Min	Mean	Max
Intercept	-0.1760	-0.3750	-0.1550	-0.1970
Family Poverty	0.0040	0.0010	0.0030	0.0060
Precipitation	-0.0010	-0.0011	-0.0010	-0.0009
Levels of Edu.	18.645	10.602	17.100	20.781
DFR2013	0.0960	0.0780	0.0920	0.1110
DFR2014	0.0790	0.0680	0.0810	0.0890
DFR2015	-0.0310	-0.0718	-0.0270	0.0100
DFR2016	0.0032	-0.0110	0.0030	0.0199
DFR2017	0.4070	0.3710	0.4020	0.4390

In Table 7, we can see that there are not too much variance on precipitation since those community centres are on the same climate. Other external factors also don't show any big variance expect levels of education that have the biggest local parameters coefficient levels. The summarty of the local coefficient estimates has the similar result of summary of global models (compare Table 6 and 7).
We decided to divide the local coefficient estimates into five intervals. Those five intervals are very weak (green), weak (light green), middle (orange), strong (blue) and very strong (red). The reasons why we divide into five intervals so we can find out in detail which community health centres have very strong until very weak correlation to the external factor. In this research, all the local coefficient are all either positive or negative value (there is no mixture between positive and negative values). Because of that, we define the values from the lowest to the highest and all of the valus are in absolute value.

The interval from all of the external factors are calculated by substract the minimum local coefficient and max local coefficient then divided by five. The local coefficient estimates for family povery percentage are varied from 0.00161 to 0.00623 where all the local coefficients are in positive value. The colour map of local coefficient estimates of Family Poverty Percentage (FPP) is presented in Figure 8.

Those 4 regions that have strong correlation are Gunung Anyar (FPP = 13.16%, DFR = 1.36, and DFI = 8); Kalirungkut (FPP = 20,4%, DFR = 1.09, and DFI = 6); Medokan Ayu (FPP = 20.34, DFR = 2.55 and DFI = 16); and Siwalankerto (FPP = 16.86, DFR = 0 and DFI = 0). The regions that have other colour than red will not have a strong correlation as the regions that have red colour.

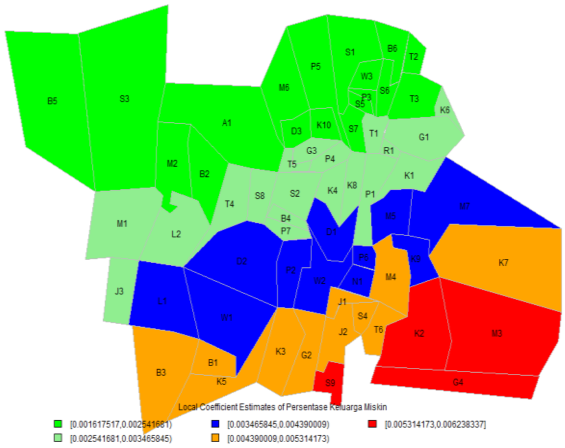

Figure 8. Local coefficient estimates of family poverty percentage

For the levels of education, the data that used for the analysis are Elementary Graduates (EG) and Senior High Graduate (SHG) as we already said before on clustering section. Levels of education are varied from 10.6 to 20.78 where all of the local coefficients are on the positive value. The colous map of local coefficient estimates of levels of education is shown in Figure 9.

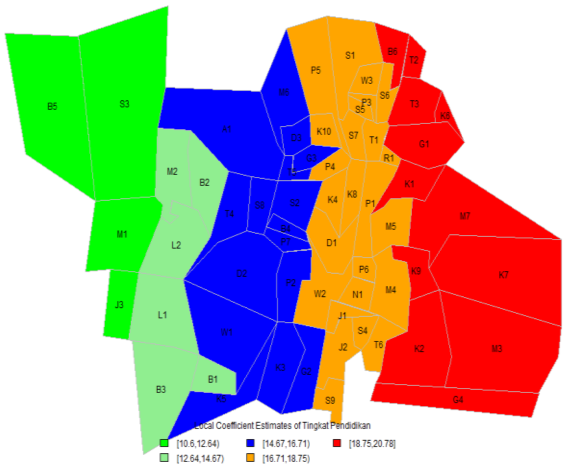

Figure 9. Local coefficient estimates of levels of education

There are 12 regions that have red colour and that means those 12 regions have a strong correlation to the levels of education on the spread of dengue fever. There are 3 regions that we already highlighted on the family poverty percentage that also included in red area of levels of education (Gunung Anyar, Medokan Ayu and Kalirungkut). Those area have high level of education where the percentage of senior high school graduate are higher than the percentage of elementary school graduate. Those area have high education but the number of dengue fever is high.

Lastly, the local coefficient estimates of precipitation which are varied from -0.00114 to -0.00098. All of the local coefficient are on the negative value. There are 5 regions that have strong correlation with precipitation. Those regions are Gunung Anyar, Kalirungkut, Keputih and Medokan Ayu (see Figure 10).

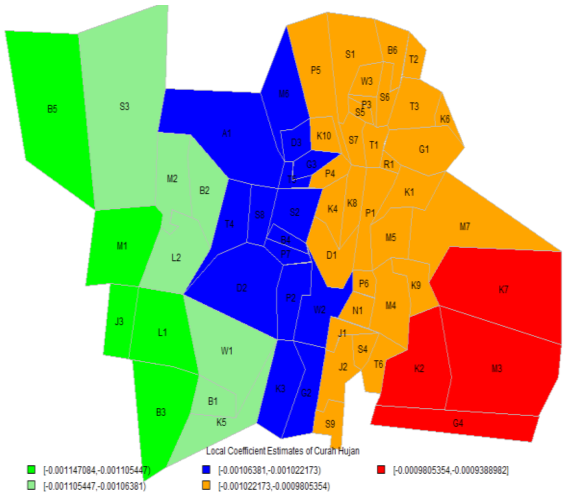

Figure 10. Local coefficient estimates of precipitation

By studying the local parameters estimate with respect to the external factors such as family poverty percentage, levels of education and precipitation we hope that the Government of Surabaya and Surabaya's public health officials can use this information to prevent the spread of dengue fever in the upcoming year.

Conclusion

In this paper, we want to know the external factors that influence on spreading of dengue fever in Surabaya. At first, we summarize the data and then clustered it with k-medoids clustering and we find that levels of education have influence on spreading dengue fever because cluster that have lower education have higher DFR and DFI that the cluster that have higher eduction. The next step is exploring statistical learning such as simple linear regression and geospatial weighted regression with external factor and DFR2013-DFR2017 to predict DFR2018. We find out that geospatial weighted regression is the best model for solving the problem than others model. In GWR, we also studying the characteristics of local parameters estimate with family poverty percentage, levels of education and precipitation. The results of local coefficient estimates is that only levels of education have significant strong correlation on spreading dengue fever in Surabaya because the value of local coefficient estimates is the highest among the other factors. We also found out that low precipitation have higher chance of spreading dengue fever because the mosquito can grow effectively in small water reservoir. As a result, we hope that the Government of Surabaya and Surabaya's public health officials can use this information as a reference to prevent dengue fever spread in the future.

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