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Spatial Clustering Using Generalized LASSO on the Gender and Human Development Index in Papua Island in 2022

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Abstract

Equitable development from a gender perspective needs attention. Based on data from the World Economic Forum (WEF), gender equality in Indonesia has increased. Even so, the island of Papua is still very low on gender equality. It can be seen from the Gender Development Index (IPG) from the Central Bureau of Statistics (BPS), there is a considerable gap between the Papua Island IPG and the National. IPG is a comparison between the Human Development Index (IPM) for Men and Women. Based on these conditions, this study aims to classify IPG, Male IPM, and Female IPM by region using the spatial clustering method in 2022. One of the analytical methods that can overcome these conditions is Generalized LASSO. Generalized LASSO can be used on data that only has a response variable (y) for clustering. Generalized LASSO clustering uses a penalty matrix D. The formation of the D matrix is formed by giving values -1 and 1 for areas that intersect or are adjacent and a value of 0 for other areas. The best clustering for IPG uses KNN with K = 3 and the number of clusters formed is 2 clusters. The best clustering for male IPM uses KNN with K = 2 and the number of clusters formed is 8. The best clustering for female IPM uses KNN with K = 2 and the number of clusters formed is 10 clusters.

Keywords: *Generalized LASSO; Gender Development Index; Human Development Index; Papua Island*

1. Introduction

Gender equality is fundamental for strengthening development in terms of gender. the rights of every individual, both men and women participate in development [1]. Development is an achievement that is expected to be equitable and fair both between generations, ethnicities, genders and regions to be important in the development process as one of the collective agreements that have been agreed globally [2]. Indonesia obtained a gender inequality index score of 0.697 (an increase of 0.009 from 0.688 from the previous year) [3]. This shows the success of the Indonesian government in its efforts to equate men with women to be involved in development. Indonesia has tended to experience an increase over the past few years. Even so, Indonesia's ranking is still at the bottom, which is ranked 92nd out of 146 countries. The achievement of Indonesia's gender equality ranking over the past decade has been quite fluctuating. The WEF gender inequality index has a

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score system on a scale of 0-1. A score of "0" indicates a very wide gender inequality, and a score of "1" indicates the achievement of gender equality. Based on data from the Central Statistics Agency (BPS), Papua and West Papua Provinces are the lowest Gender Development Index (IPG) in Indonesia [4]. The Gender Development Index (IPG) is an index of achievement of basic human development capabilities which is the same as the Human Development Index (IPM) by taking into account the gender inequality of men and women, in other words, IPG is a comparison of male IPM and female IPM. BPS noted that the IPG of Papua Province has increased, in 2020 by 79.5, increased to 80.16 in 2021, and increased again in 2022 with an index of 81.04. Meanwhile, West Papua Province continues to increase also from 2020 to 2022, recorded the IPG of West Papua Province in 2020 at 82.91, increased in 2021 to 83, and the index increased again in 2022 to 83.61 [5]. The condition of the IPG of Papua Province has fluctuated and West Papua Province has increased in the last 3 years. This cannot be generalized to all districts/cities in Papua and West Papua Provinces. IPG Districts/Municipalities in Papua and West Papua Provinces experience various conditions, some of which have decreased, increased, and fluctuated. Based on the Law, Papua Island is currently developing into 6 provinces, namely Papua, West Papua, Southwest Papua, Mountain Papua, Central Papua, and South Papua. The development of provinces in Papua does not increase the number of regencies/cities. This study seeks to group districts/cities in Papua Island which has the same range of IPG, Male IPM, and Female IPM. Based on these conditions, clustering that occurs in districts / cities in 2022 will be analyzed by spatial clustering analysis. One method of analysis that can solve these conditions is Generalized LASSO. According to Tibshirani and Taylor (2011), the Generalized LASSO method can be used on data that only has a response modifier (y) for clustering by identifying matrix D according to the number of rows with intersecting or adjacent regions. Matrix D is formed based on neighboring and adjacent areas using KNN by giving values of -1 and 1 for neighboring or adjacent areas and 0 values for other areas. Matrix D will be used for clustering of each region.

2. Methods

This study used data from the Central Statistics Agency (BPS) which is secondary data. The data is taken from BPS published in 2023. The data consists of IPG, Male IPM, and Female IPM in 42 regencies/cities on Papua Island. The steps used in conducting the analysis in this study are:

2.1. Data exploration

The exploration carried out in this study looked at the spread of IPG, Male IPM, and Female IPM districts/cities in Papua Island in 2022 using maps. Data analyzed using Generalized LASSO must be normal because Generalized LASSO is derived from OLS. OLS has an assumption of normality that must be fulfilled [6]. Checking normality using the powerTransport function located in the car library.

a.) Checking the normality of the Y variable in IPG, Male IPM, and Female IPM with the Shapiro-Wilk test using the following equation (Shapiro and Wilk 1965):

$$W = \frac{\sum_{i=1}^{n} \left(a_i \left(y_{n-i+1} - y_i\right)\right)^2}{\sum_{i=1}^{n} \left(y_i - \bar{y}\right)^2} \tag{1}$$

where a_i is the Shapiro-Wilk coefficient. The number of used a_i is $\frac{n}{2}$ (rounded down if decimals are present), y_{n-i+1} is the $(n-i+1)$-st data, y_i is the i-th data, and $\bar{y}$ is the average data.

The hypothesis is:

H_0 : The data is normally distributed, if the p-value is greater than the significance level (5%)

H_1 : The data is not normally distributed, if the p-value is less than the significance level (5%)

The desired Shapiro-Wilk test decision criterion is to accept H_0.

b.) Perform a transformation using power Transform if y is abnormal.

c.) Checking normalcy again with Q-Q Plot.

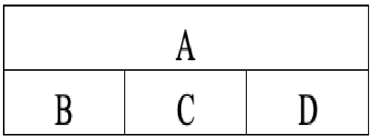

Figure 1. Area illustration

d,) Exploration of data on IPG, Male IPM, and Female IPM using maps.

2.2. Neighbor identification using K – Nearest Neighbor and formation matrix D

This algorithm works by finding the closest k number of patterns with input patterns, then determine the decision class based on the highest number of patterns among these k patterns (Suyanto 2018). Identification neighbors used using ladders, KNN with k = 2, and KNN with k = 3. This identification is to determine the clustering. Clustering IPG, Male IPM and Female IPM by looking at Changes. The formation of matrix D has 2 methods as follows.

1.) The formation of matrix D is determined by tangent regions. Area illustration shows intersecting regions where region A intersects with regions B, C, and D. Region B intersects with regions A and C, region C intersects with regions A, C, and D, and region D intersects with regions A and C. The matrix D_1 is matrix D as an illustration of the formation of matrix D from Figure **??**, which can be defined as follows.

$$\mathrm{D}_1 = \begin{pmatrix} A & B & C & D \\ -1 & 1 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ -1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \\ 0 & 0 & -1 & 1 \end{pmatrix} \quad (1)$$

2.) The formation of matrix D is determined by the neighborly region using KNN with $K = 2$ and $K = 3$. The area illustration shows that using KNN with $K = 2$, region A has 2 nearby regions, namely B and C; region B has 2 nearby regions, namely A and C; region C has 2 nearby regions, namely A and D; and region D has 2 nearby regions, namely A and C. Matrix D_2 is matrix D as an illustration of the formation of matrix D using KNN with $K = 2$ from Figure **??**, which is defined as follows.

$$\mathrm{D}_2 = \begin{pmatrix} A & B & C & D \\ -1 & 1 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 0 & -1 & 1 & 0 \\ 0 & 0 & -1 & 1 \\ -1 & 0 & 0 & 1 \end{pmatrix} \quad (2)$$

The area illustration shows using KNN with K = 3 that region A has 3 nearby regions namely A, B and C, region B has 3 nearby regions namely A, B and C, region C has 3 nearby regions, namely A, B and D, and region D has 3 nearby regions namely A, B and C. Matrix D3 is matrix D as an illustration of the formation of matrix D using KNN with K = 3 from Figure 1 which can is defined as follows.

$$
D_3 = \begin{pmatrix} A & B & C & D \\ -1 & 1 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ -1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \\ 0 & -1 & 0 & 1 \\ 0 & 0 & -1 & 1 \end{pmatrix} \tag{3}
$$

In the same way as the illustration of matrix D formation above, Papua Island has a matrix D shape measuring 89 x 42 for districts/cities with neighboring areas, matrix D measuring 56 x 42 for districts/cities with K = 2, and matrix D is 82 x 42 for districts/cities with K = 3.

2.3. Generalized LASSO

LASSO (Least Absolute Shrinkage and Selection Operator) is a method to minimize the number of squared errors of the OLS (Ordinary Least Square) process by adding an L1 penalty [6]. This method conjectures the regression coefficient by minimizing the residual value plus the penalty L1. The equation for estimating the regression coefficient with LASSO analysis [7] is as follows.

$$
\hat{\beta} = \underset{\beta \in \mathbb{R}^p}{\operatorname{argmin}} \frac{1}{2} \|y - X\beta\|_2^2 + \lambda \|\beta\|_1 \tag{2}
$$

where y is the response variable vector with dimensions n x 1, X is the free variable matrix with n x n dimensions, β is the n x 1 parameter vector, and λ is the tuning parameter coefficient. The Generalized LASSO method can be used on data that only has a response modifier (y) for clustering by identifying matrix D according to the number of rows with intersecting regions. The coefficient estimator equation for Generalized LASSO Regression [8]is as follows.

$$
\hat{\beta} = \underset{\beta \in \mathbb{R}^p}{\operatorname{argmin}} \frac{1}{2} \|y - X\beta\|_2^2 + \lambda \|D\beta\|_{(1)} \tag{3}
$$

where y is a response variable vector with dimensions n x 1, X is the identity matrix of the free variable n x p, β is the vector parameter p x 1, λ is the tuning parameter coefficient, and D is a matrix with dimensions based on tangent regions used to form a structure that describes the spatial neighborly structure formed in the data

2.4. Selecting the optimum λ with the Approximate Leave One Out Cross Validation (ALOCV)

Cross validation is typically used to determine tuning parameters. In the case of Generalized LASSO, cross validation such as k-fold cross validation and leave one out cross validation (LOOCV) is not appropriate because some data points from the training data will be used as test data resulting in changes to the matrix D that has been formed, so cross validation needs to be modified. One way is to modify LOOCV to ALOCV. ALOCV is a modification of LOOCV that can calculate approximations from the leave one out data used so that it will not change the matrix D that has been formed. The equation of LOOCV [9] is as follows.

$$
\text{LOOCV}(\lambda) = \frac{1}{n} \sum_{c=1}^{n} \left(y_c - x_c^T \hat{\beta}_{(-c)} \right)^2 \tag{4}
$$

Stages of ALOCV work [10]:

a. Estimate β in equation (2).

b. Estimate u from equation (2) to calculate λ by the following equation:

$$\hat{u_s} = \underset{\gamma,u}{\text{argmin}}\frac{1}{2}\|\gamma - y\|_2^2 \quad \text{s.t.} \quad \|u\|_\infty \leq \lambda \text{ and } X^T\gamma = X^T u \tag{5}$$

c. Delete the matrix row D that belongs to the index set $E = \{s = 1, ..., m : |\hat{u}_s| = \lambda\}$, to form the submatrix $D_{(-E)}$.

d. Forms matrix $A = XB$, where matrix B has empty columns of matrix $D_{(-E)}$ and X is the identity matrix.

e. Calculates the matrix $H^* = AA^+$ where A^+ is the Moore-Penrose pseudoinverse of A.

f. Calculates the ALOCV error with the following equation:

$$\text{ALOCV}(\lambda) = \frac{1}{n}\sum_{c=1}^{n}\left(\frac{y_c - x_c^T\hat{\beta}}{(1 - h_{cc}^*)}\right)^2 \tag{6}$$

where h_{cc}^* is the diagonal component of the matrix H^*.

The determination of selected λ is the minimum of ALOCV error. ALOCV can produce slightly smaller sample prediction errors and can detect edges in graphs with shrinking differences more precisely compared to cross-validation k-fold [11]

2.5. Clustering using Generalized LASSO by using predetermined matrix D using λ optimum selected

2.6. Checking district/city groups for IPG, Male IPM, and Female IPM in 2022

2.7. Interpretation of results

3. Result and Discussion

3.1. Data exploration

Data exploration is the first step in this research. Exploration used to find out the picture of data before analysis. Exploration of initial data shows the distribution of IPG and IPM in Papua Island by using maps in 2022.

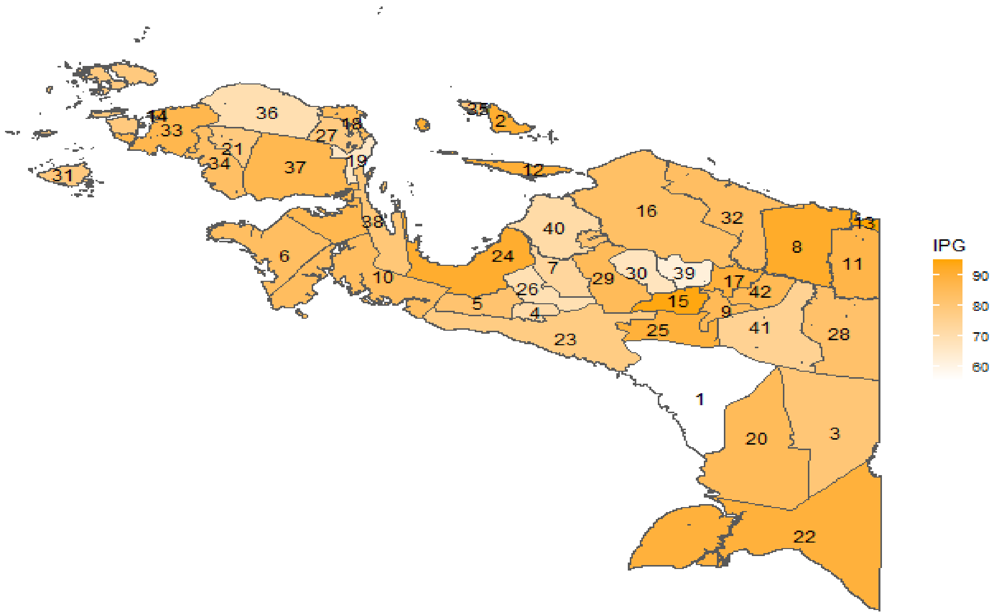

Figure 2. Map of IPG distribution of Papua Island 2022

information:

Table 1. Map of the distribution of IPM

No	Nama Kabupaten	no	Nama Kabupaten	No	Nama Kabupaten
1	Asmat	15	Lanny Jaya	29	Puncak
2	Biak Numpor	16	Mamberamo Raya	30	Puncak Jaya
3	Boven Digoel	17	Mamberamo Tengah	31	Raja Ampat
4	Deiyai	18	Manokwari	32	Sarmi
5	Dogiyai	19	Manokwari Selatan	33	Sorong
6	fakfak	20	Mappi	34	Sorong Selatan
7	Intan Jaya	21	Maybrat	35	Supiori
8	Jayapura	22	Merauke	36	Tambrauw
9	Jawawijya	23	Mimika	37	Teluk Bintuni
10	Kaimana	24	Nabire	38	Teluk Wondama
11	Keerom	25	Nduga	39	Talikara
12	Kepulawan Yapen	26	Paniai	40	Waropen
13	Kota Jayapura	27	Pegunungan Afrak	41	Yahukimo
14	Kota Sorong	28	Pegunungan Bintang	42	Yalimo

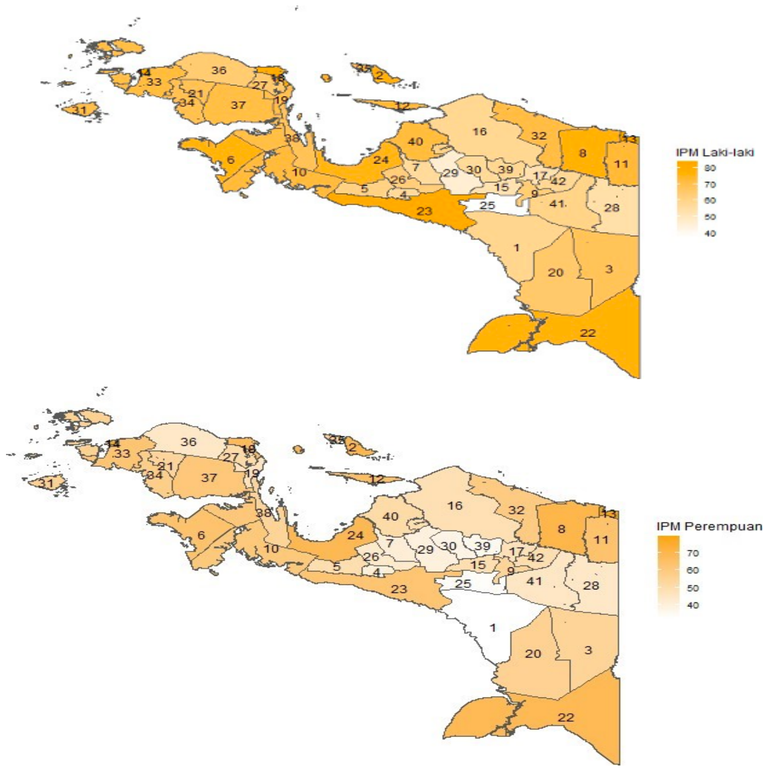

Figure 3. (a) Map of the distribution of IPM for Men in Papua Island 2022 (b) Map distribution of IPM for Women in Papua Island 2022

The distribution of IPG and IPM needs to be checked for normality before continuing spatial clustering analysis with Generalized LASSO. The Shapiro-Wilk test has shown the most consistent yield trend compared to other tests when evaluated against the results of the Skewness-Kurtosis test, achieving a high consistency level of 90.48% [12]. This test is suitable for calculating the p-value with data measuring $4 < n < 2000$ (Royston, 1992). The Shapiro-Wilk test results for IPG, Male IPM, and Female IPM displayed p-values of 0.04559, 0.3676, and 0.85, respectively. The p-value for IPG is less than 5% alpha, leading to the rejection of the null hypothesis (H0) or providing sufficient evidence to conclude that the response modifier is not normally distributed. Meanwhile, the p-values for Male IPM and Female IPM, 0.3676 and 0.85 respectively, are greater than 5% alpha, leading to the rejection of the alternate hypothesis (H1) or providing sufficient evidence to claim that the response modifiers are normally distributed.

IPG needs data transformation using a Power Transform method. This transformation involves finding the value of α. The obtained value for α is 3.83. Post-transformation, the resulting p-value is 0.7317. Given that the p-value is significantly larger than 5% alpha, the alternate hypothesis (H1) is rejected, providing sufficient evidence to conclude that the variable Y is normally distributed.

3.2. Determination of Penalty Matrix from KNN

The Penalty Matrix D is determined by looking at adjacent regions. Matrix D is formed using neighboring regions, KNN with K = 2 and KNN = 3 adjacent regions. Matrix D for regions neighborly by 89 x 42, matrix D for 2 adjacent regions by 56 x 42, and matrix D for 3 adjacent regions by 82 x 42. This matrix D will be used to cluster each region.

3.3. Comparison of λ and ALOCV

Table 2. Comparison of λ and ALOCV for each D at IPG, Male IPM, and Female IPM

Penggerombolan	CV	D Ketetanggan	D KNN-2	D KNN-3
	λ	3099179	16105644	7263420
IPG	min ALOCV error	9.80	7.57	6.91
	banyak gerombol	12	3	2
	λ	22.09	10.34	11.78
IPM Laki-laki	min ALOCV error	101.13	75.64	88.7
	banyak gerombol	2	8	2
	λ	13.28	9.75	9.19
IPM Perempuan	min ALOCV error	4200743	109.6	128.62
	banyak gerombol	3	10	3

The best λ selection is λ taken from the smallest ALOCV value for each matrix D. This selection of the best λ is used to clustering of each matrix D on IPG, Male IPM, and Female IPM. The λ range used for IPG is 995815.2 to 30622805.8, the λ range used for Male IPM is 1.37 to 44.7, and the λ range used for Female IPM is 2.37 to 37.81.

Table 1 shows that the best IPG cluster has λ by 16105644, min ALOCV error of 6.91, and 2 clusters. On Table 1 also indicates that the best Male IPM cluster has λ 10.34, min ALOCV error of 75.64, and 8 clusters. Finally, Table 1 indicates that the best female IPM has λ of 9.75, min ALOCV error 109.6, and 10 clustering.

3.4. Generalized LASSO

Clustering using Generalized LASSO can be seen on Figures 6, 7, and 8. Figure 6 is the best IPG cluster with The ALOCV is 6.91 with KNN-3 using a matrix D of 82 x 42. Figure 7 is a cluster of the best Male IPM with ALOCV of 75.64 with KNN-2 using a matrix D of 56 x 42. Figure 8 is a cluster of Female IPM with an ALOCV of 109.6 with KNN-2 using a matrix D of 56 x 42

3.5. Interpretation of Results

Table 3 shows that the best IPG swarms in Papua Island using D of 82 x 42 with KNN-3 there are 2 clusters. Cluster 1 It consists of 23 regions and cluster 2 consists of 19 regions. Cluster 1 is a group that has a relatively low IPG and a group of 2 is a group that has a relatively high IPG. In figure 6 It can be seen that the more to the west the lower and the more to the east the more its high IPG.

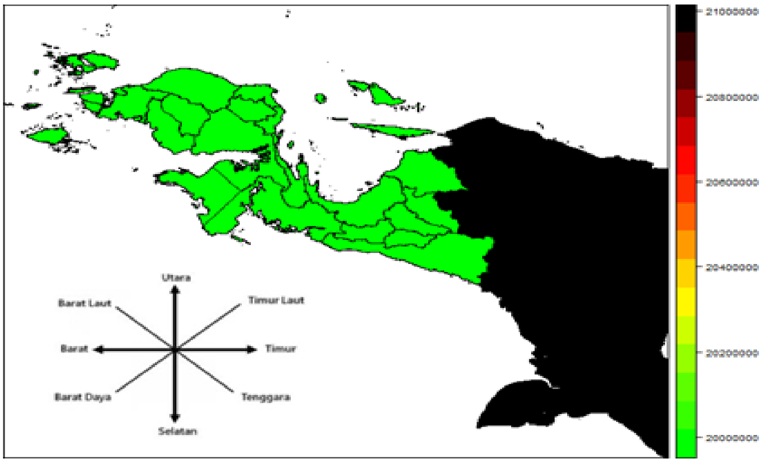

Figure 4. Clustering IPG using matrix D of 82 x 42 with KNN-3

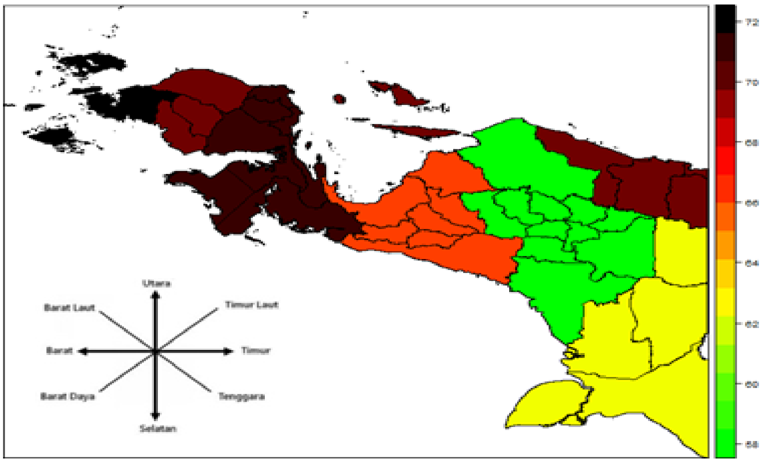

Figure 5. Clustering Male IPM using matrix D of 56 x 42 with KNN-2

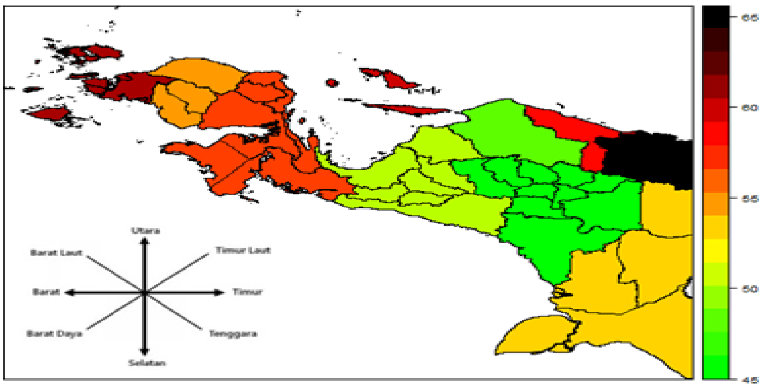

Figure 6. Clustering of Female IPM using matrix D 56 x 42 with KNN-2

Table 4 shows that the best Male IPM cluster using D of 56 x 42 with KNN-2 there are 8 cluster. Cluster 1 It consists of 11 regions, cluster 2 consists of 4 regions, cluster 3 consists of 7 region, cluster 4 consists of 3 regions, cluster 5 consists of 3 regions, cluster 5 consists of 3 regions, cluster 6 consists of 4 regions, cluster 7 It consists of 7 regions, and the cluster of 8 consists of 3 regions. Cluster 1 classified low to cluster 8 is classified as high IPM male. By figure 7, Low male IPM in the East and West Quite a variation from low to high.

Table 3. The best clustering of IPG

Clustering	Cluster	Regency or City
IPG	1	Biak Numpor, Deiyai, Dogiyai, Fakfak, Intan Jaya, Kaimana, Kepulauan Yapen, Kota Sorong, Manokwari Selatan, Maybrat, Mimika, Nabire, Paniai, Pegunungan Arfak, Raja Ampat, Sorong, Sorong Selatan, Supiori, Tambrau, Teluk Bintuni, Teluk Wondama, dan Waropen
	2	Asmat, Boven Digoel, Jayapura, Jayawijaya, Keerom, Kota Jayapura, Lanny Jaya, Mamberamo Raya, Mamberamo Tengah, Mappi, Merauke, Nduga, Pegunungan Bintang, Puncak, Puncak Jaya, Sarmi, Tolikara, Yahukimo, dan Yalimo

Table 4. The best clustering of Male IPM

Clustering	Cluster	Regency or City
IPM Laki-laki	1	Asmat, Jayawijaya, Lanny Jaya, Mamberamo Raya, Mamberamo Tengah, Nduga, Puncak, Puncak Jaya, Tolikara, Yahukimo, dan Yalimo
	2	Boven Digoel, Mappi, Merauke, dan Pegunungan Bintang
	3	Deiyai, Dogiyai, Intan Jaya, Mimika, Nabire, Paniai, dan Waropen
	4	Biak Numpor, Kepulauan Yapen, dan Supiori
	6	Jayapura, Keerom, Kota Jayapura, dan Sarmi
	7	Fakfak, Kaimana, Manokwari, Manokwari Selatan, Pegunungan Arfak, Teluk Bintuni, dan Teluk Wondama
	8	Kota Sorong, Raja Ampat, dan Sorong

Table 5. The best clustering of Female IPM

Clustering	Cluster	Regency or City
Female IPM	1	Asmat, Jayawijaya, Lanny Jaya, Mamberamo Tengah, N
2	Mamberamo Raya	
	3	Deiyai, Dogiyai, Intan Jaya, Mimika, Nabire, Paniai, dan Waropen
	4	Boven Digoel, Mappi, Merauke, dan Pegunungan Bintang
	5	Maybrat, Sorong Selatan, dan Tambrauw
	6	Fakfak, Kaimana, Manokwari, Manokwari Selatan, Pegunungan Arfak, Teluk Bintuni, dan Teluk Wondama
	7	Sarmi
	8	Biak Numpor, Kepulauan Yapen, dan Supiori
	9	Kota Sorong, Raja Ampat, dan Sorong
	10	Jayapura, Keerom, dan Kota Jayapura

Table 5 shows that the best Female IPM cluster using D with KNN-2 there are 10 clusters. Cluster 1 consists of 10 region, cluster 2 consists of 1 region, cluster 3 consists of 7 regions, Cluster 4 consists of 4 regions, cluster 5 consists of 3 regions, cluster 6 It consists of 7 regions, cluster 7 consists of 1 region, cluster 8 consists of 3 Regions, cluster 9 consists of 3 regions, and cluster 10 consists of 3 regions. Group 1 is classified as low and group 10 is classified as high in Female IPM his. Figure 8 shows that in the Northeast, Women's HDI is classified as The height and other parts vary quite a bit from low to high.

Cluster IPG, Male IPM, and Female IPM based on same beta value. If the beta values are the same then it is clustered on one cluster. If the beta value is different from the others, then cluster on one cluster.

4. Conclusion

At the best IPG cluster with an ALOCV of 6.91 using D of 82 x 42 with KNN-3 there are 2 clustering. Cluster 1 is low and cluster 2 is high with the further west the lower the IPG and the further east the more its high IPG. At the best male IPM cluster with ALOCV of 75.64 using D of 56 x 42 with 2 KNN-2 there are 8 clusters. The lowest clusters consist of Asmat, Jayawijaya, Lanny Jaya, Mamberamo Raya, Mamberamo Tengah, Nduga, Puncak, Puncak Jaya, Tolikara, Yahukimo, and Yalimo as well as the highest clusters Sorong City, Raja Ampat, and Sorong. Male IPM classified as The height being in the East and the Western part is quite a variation from low to tall. On the best Female IPM swarm with ALOCV 9.19 using D of 56 x 42 with KNN-2 there are 10 clustering. The lowest cluster consists of Asmat, Jayawijaya, Lanny Jaya, Central Mamberamo, Nduga, Peak, Puncak Jaya, Tolikara, Yahukimo, and Yalimo and the highest clusters consisting of Jayapura, Keerom, and Jayapura City. Female IPM is high in the Northeast and The other parts are quite varied from low to high.

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