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RESEARCH ARTICLE

Flood Disaster Risk Model in Karawang Regency's Industrial Area, West Java Province, Indonesia

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Abstract. Telukjambe Barat and Telukjambe Timur Sub-Districts, Karawang Regency, have a high flood risk level due to changes in Land Use/Land Cover and the yearly occurrence of runoff water discharge. This research aims to analyze the rate and pattern of land-use change due to industrial development, examine the correlation of flood impacts with environmental-socio-economic factors, and develop a flood risk model in industrial areas. Data were collected through methods of system dynamics, remote sensing, geographic information system, questionnaire distribution, focus group discussions, and in-depth interviews with stakeholders. The results showed that floods in this regency are due to massive inland changes, such as the transition from vegetation and water bodies to industrial and residential areas and a strong relationship between environmental-social-economic factors. In other cases, areas with urban land conversion are likely to be flood-prone zones in places such as the Philippines, Belgium, and China. Based on the correlation test that has been conducted, the relationship with the highest level of closeness is the correlation between environmental factors and the impact of flooding, which has a value of 0.791. Therefore, the disaster risk model with an integrated spatial plan approach and an ecological perspective is an option for realizing sustainable development in industrial areas in Karawang Regency.

1.Introduction

Karawang Regency is known as one of the substantial agricultural establishments that manufactures and supplies rice to West Java and other provinces in Indonesia. The central government pays great attention to this region by ensuring the proper conversion of agricultural land and infrastructure development, such as irrigation canals, which yields positive results because this regency is the mainstay of export commodities to neighboring countries (Widiatmaka *et al*., 2013). According to Janti (2019), this regency was dubbed the national rice granary of West Java, with a production range of 25.8 million tons until the late 80s. However, the government has threatened this nickname since the 90s due to industrialization and settlement development (Sopyan, 2014).

This industrial area has contributed significantly to portraying this regency as the region with the third largest Gross Regional Domestic Product (GRDP) in West Java. In 2016, its GDP was recorded at IDR 182.7 trillion, the highest contributor in the manufacturing sector with IDR 130.7 trillion, equivalent to 71.5% of the total regional domestic product (BPS, 2017). The existence of this Industrial area plays a strategic role in promoting economic activities in the surrounding area. Changes in land use from non-agricultural to industrial have positively correlated with GRDP (Setyowati *et al*., 2015). The uncontrollable, rapid and massive land conversion requires appropriate planning according to future needs. Therefore, it is essential to know the changes in land use in Karawang Regency to determine the effects.

Changes in non-agricultural land are characterized by the growth of industrial areas (Tian *et al.*, 2017). The rapid changes in land processes tend to be described by the movement of people from villages to cities accompanied by the transformation of agricultural lands into urban areas (Guan *et al.*, 2011). Data from the Agriculture Office of Karawang Regency showed over 2,578 ha of lands were converted to industrial and residential areas from 1989 to 2007 and were used to analyze spatial models of land occupations for a certain period (Dachlan & Rosmarini, 2016). Technically, the fluctuation rates of land-use change are spatially analyzed using remote sensing data and geographic information systems. The collection, processing, and final delivery results of these 2 are used to build an appropriate land use model for future requirements. The perception of this regency as an Industrial Area certainly has an enormous and sustainable impact on the neighboring regions in terms of socioeconomic and land use.

The dynamics of changes in land use are associated with urban population growth. In a research case of Africa, urban land expansion is more linked to population growth than to a rise in Gross Domestic Product (GDP) (Seto *et al*., 2011). In addition, the increase in agricultural yields creates more production land to produce the rising demand for crops and population. This case is often found in various developing countries where people tend to migrate for better life opportunities which cause changes in land use/land cover (Pandey, 2013). Another research case in the Wallonia region (Belgium) revealed that the increase in total flood risk damages would be outstanding from one urbanization situation to another (Mustafa *et al.,* 2018). A similar case was also found in the Philippines, where approximately 14,000 ha of urban land conversion made the area a flood-prone zone affecting 5.6 million urban residents (Johnson *et al.*, 2021). According to Luo & Zhang (2022), land use/land cover changes have affected some cities in China with an increase in flood risk and a decrease in regulation services. Therefore, addressing urban population growth in flood-themed research related to land-use changes is important.

The study area of Telukjambe Barat and Telukjambe Timur Sub-Districts, Karawang Regency, is depicted in Figure 1. The development of the Karawang Regency area is significantly influenced by the action of transportation facilities and infrastructure, which is careful planning to avoid sporadic growth (Siagian, 2011). Irene (2015) stated that approximately 181.87 Ha of farmland were yearly converted to an industrial area and other land use from 1999 to 2005.

According to Liao (2012), urbanized floodplains are systems where climate, social and economic conditions, built systems, and riverine processes affect flood hazards and disasters. Based on data from BPBD, Telukjambe Barat and Telukjambe Timur experienced a 50 to 100 cm and 150 to 200 cm groundwater level in 2014. However, in 2015, the floods only occurred in 2 sub-districts, namely Pakisjaya and Telukjambe Barat (BPBD Karawang, 2021).

In 2017, a flood occurred in 12 sub-districts, including Jatisari and Telukjambe Barat, with a maximum water level of approximately 100 to 150 cm. Meanwhile, none was witnessed in Telukjambe Timur. In 2018, a decrease was recorded in 6 sub-districts, namely Telukjambe Barat, Karawang, Cikampek, Purwasari, Rawamerta, and Cilebar.

In 2019, the number of flood locations increased to 6 sub-districts, including Telukjambe Barat, with puddles as high as 100 to 150 cm. In 2020, floods almost inundated all sub-districts in Karawang, with worst-case scenarios recorded in Telukjambe Barat and Pangkalan, excluding 5 sub-districts. All the flood maps in Karawang Regency from the year 2014 to 2019 are presented in Figure 2.

The research location is focused on Telukjambe Barat and Telukjambe Timur Sub-Districts, Karawang Regency, West Java Province. These areas were selected based on the following considerations, (1) a massive land-use change in both sub-districts, (2) availability of several industrial areas, and (3) they have a history of flood events. Therefore, this research aims to analyze the rate and pattern of land-use change due to industrial development, examine the correlation of flood impacts with environmental-socio-economic factors, and develop a flood risk model in industrial areas. The flowchart of the research is presented in Figure 3. The flowchart shows the analysis, variables, and state of the art of research.

2.Methods

According to Chen (2015), two methodologies are used to assess flood disaster risk, namely qualitative and quantitative methods. This research used the analytical method based on spatial-temporal/time series with a pixel size of 30x30 m used to optimize the secondary data obtained. Land use was categorized using the supervised classification method by grouping the pixels of the image (Faisol, 2009). This method was adopted because of its

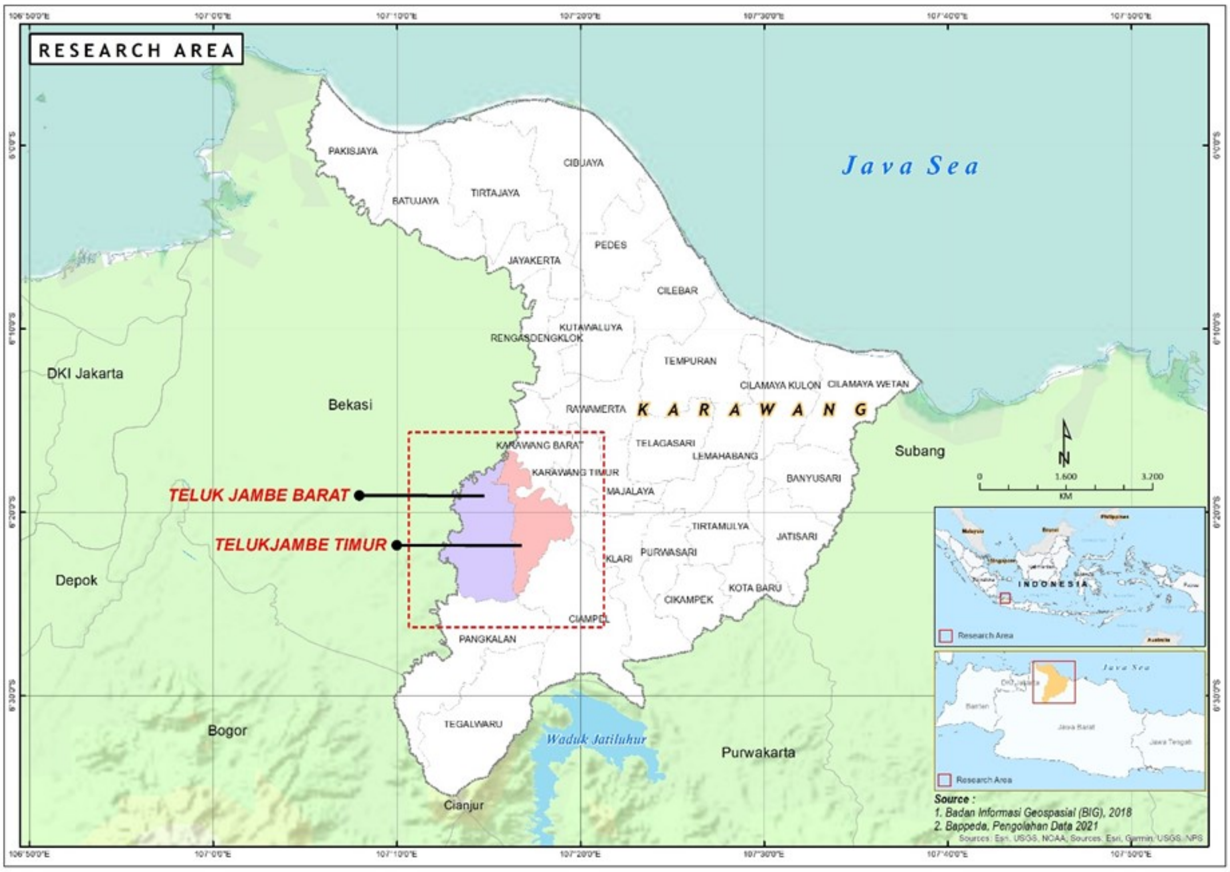

Figure 1. Research Area
Source: Processed by authors (2021)

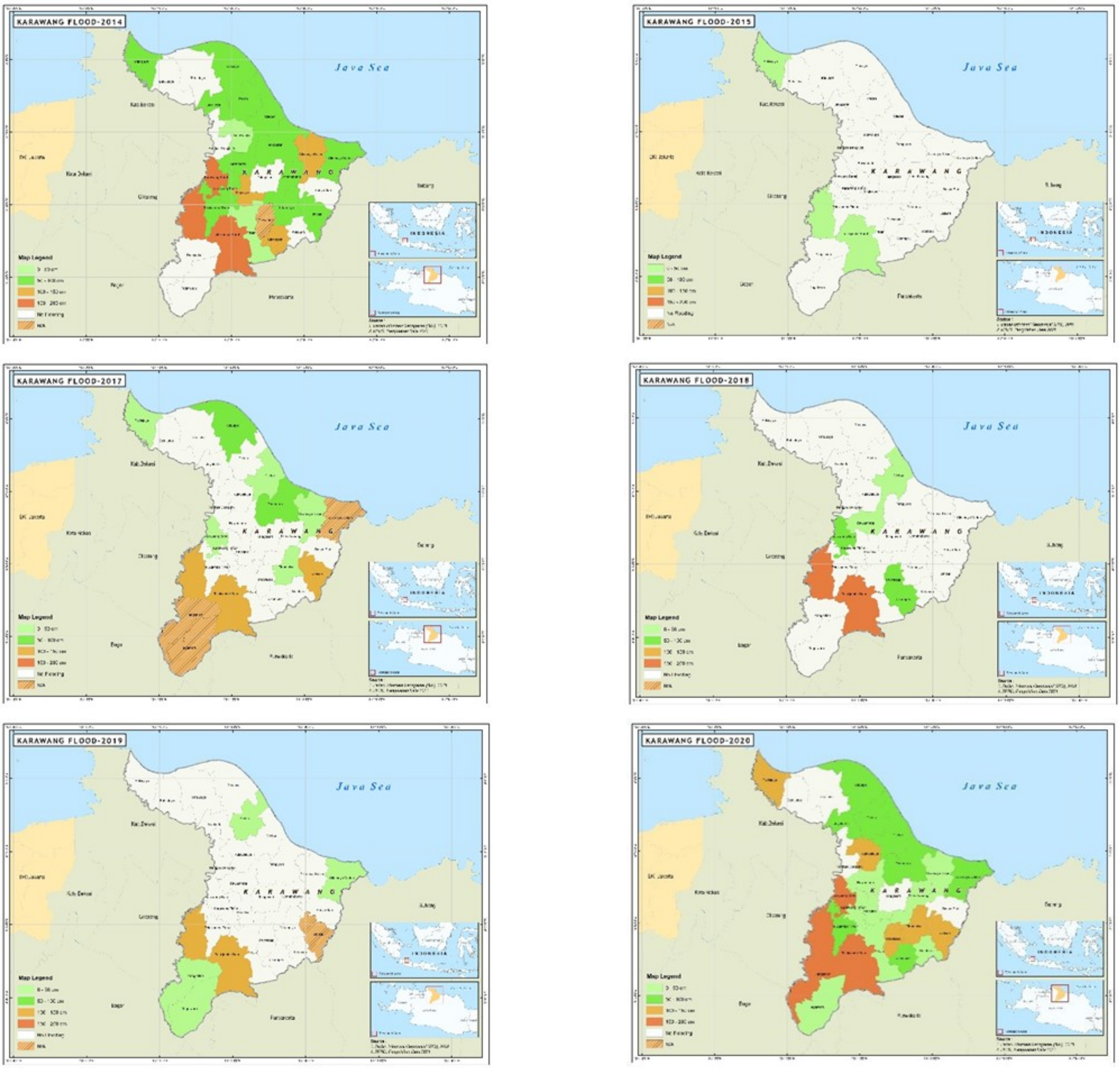

Figure 2. Flood Maps in Karawang Regency in 2014, 2015, 2017, 2018, 2019
Source: Badan Penanggulangan Bencana Daerah (BPBD) Karawang (2021).

advantages, such as classifying information based on the sample points taken and controlling its accuracy (Septiani *et al*., 2019). The classification was conducted to determine land-use changes in Karawang Industrial Area from 1989 to 2019.

The data and information used are Landsat 5 and 8 images comprising 122 paths and 64 rows, as shown in Table 1. The Landsat 5 satellite images used are recordings of 1989, 1999, and 2009, while those of Landsat 8 images are from 2019. In addition, a Topographical Map of Indonesia with a scale of 1:25,000 Karawang Regency, West Java Province, published by the Badan Informasi Geospatial (BIG), was also utilized. The first step was to download Landsat 5 and 8 images, which were then processed using ArcGIS and Envi software and followed by a radiometric correction to improve its visuals. The geographical Information System (GIS) is one tool for processing data on flood disaster risk (Mahmoud & Gan, 2018).

According to Akbari (2016), atmospheric correction is used to eliminate radiation errors recorded in the image due to scattering. It is also realized using the Dark Object Subtraction method, which falsely assumes that the pixel value of each band is zero (Ekadinata *et al*., 2008).

The next step is to crop the image concerning the research location, namely Telukjambe Barat and Telukjambe Timur Sub-Districts, to continue the supervised classification process.

The data were also collected by distributing questionnaires and conducting interviews with people residing in the location. The questionnaire contains questions on the social, environmental, and economic fields related to floodings, such as prevention efforts, adaptation strategies, and the community's perceptions of such an event in the 2 sub-districts.

The disaster risk model in Karawang industrial area is depicted in an input-output diagram, divided into uncontrolled and controlled inputs and desired and unwanted outputs. Based on the analysis of stakeholder needs and the formulation of the problem, a black box diagram was formed to illustrate the input and output of the industrial disaster risk model in the research area (Eriyatno, 2012).

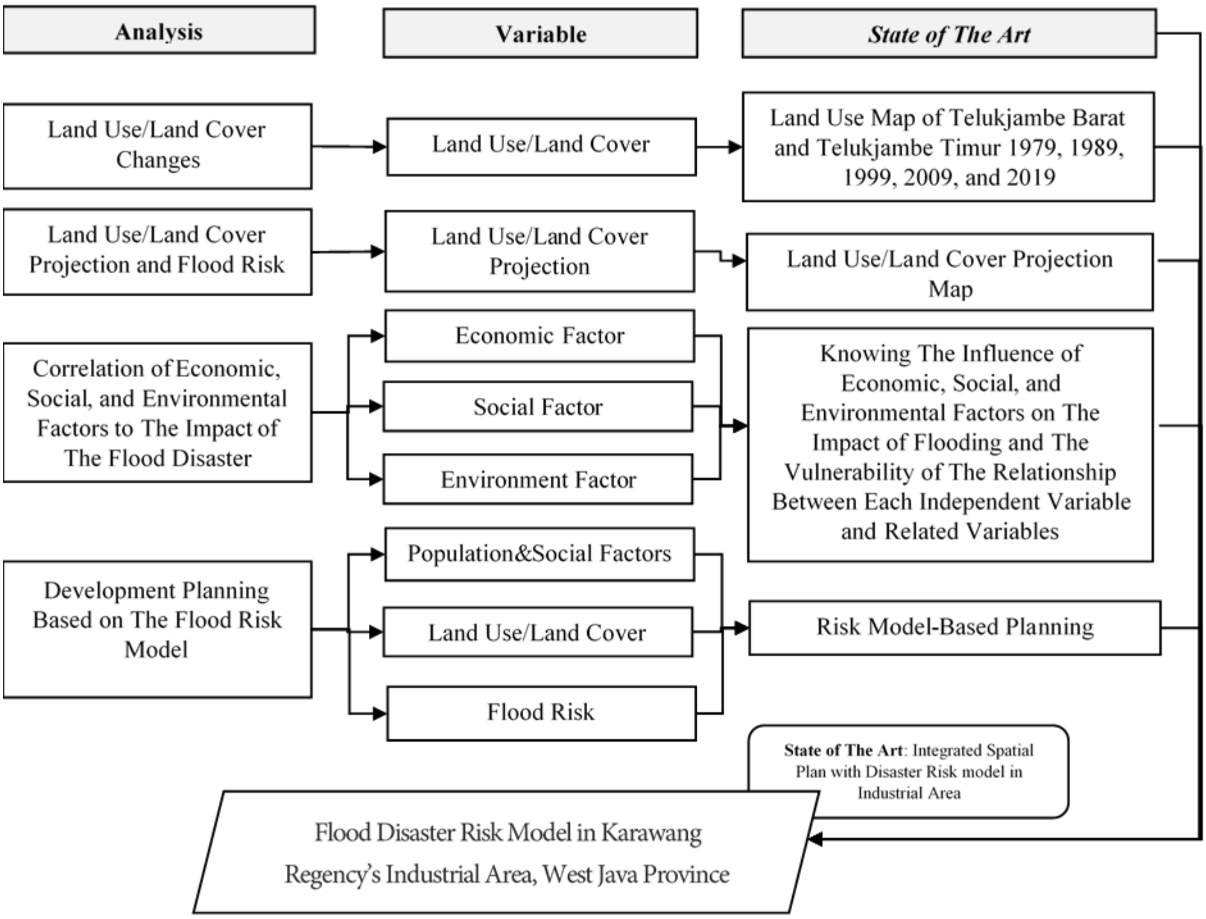

Figure 3. Research Process Flowchart
Source: Processed by authors (2021).

Table 1. Classification of Landsat 5 and 8 Image

Band	Landsat 5 Image		Landsat 8 Image	
	Wavelength (µm)	Resolution (m)	Wavelength (µm)	Resolution (m)
Band 1	0.45 - 0.52	30	0.43 - 0.45	30
Band 2	0.52 - 0.60	30	0.45 - 0.51	30
Band 3	0.63 - 0.69	30	0.53 - 0.59	30
Band 4	0.76 - 0.90	30	0.64 - 0.67	30
Band 5	1.55 - 1.75	30	0.85 - 0.88	30
Band 6	10.40 - 12.30	120	1.57 - 1.65	30
Band 7	2.08 - 2.35	30	2.11 - 2.29	30
Band 8	-	-	0.50 - 0.68	15
Band 9	-	-	1.36 - 1.38	30
Band 10	-	-	10.6 - 11.19	100
Band 11	-	-	11.50 - 12.51	100

Figure 5 shows the population growth in Karawang Regency, which is influenced by mortality and birth rates. The figure shows a scenario model based on field conditions in Karawang Regency. According to Sakti & Ikhwan (2015), population growth can be determined by births, deaths, immigration, and emigration rates. Furthermore, the development of industries attracts immigrants residing in neighboring communities.

Figure 6 is a scenario model built based on population growth in Karawang Regency, which is influenced by death and birth rates and industrial development. The land use sub-model is grouped into 4 types: industry, settlement, water body, and vegetation.

Figure 7 shows the development of a dynamic system model for predicting daily rainfall intensity. Figure 7 is a scenario model using a Flood Risk Sub-Model developed regarding the model created by Adipraja and Sulistyo (2018). Humidity and air temperature factors influence the occurrence of high rainfall.

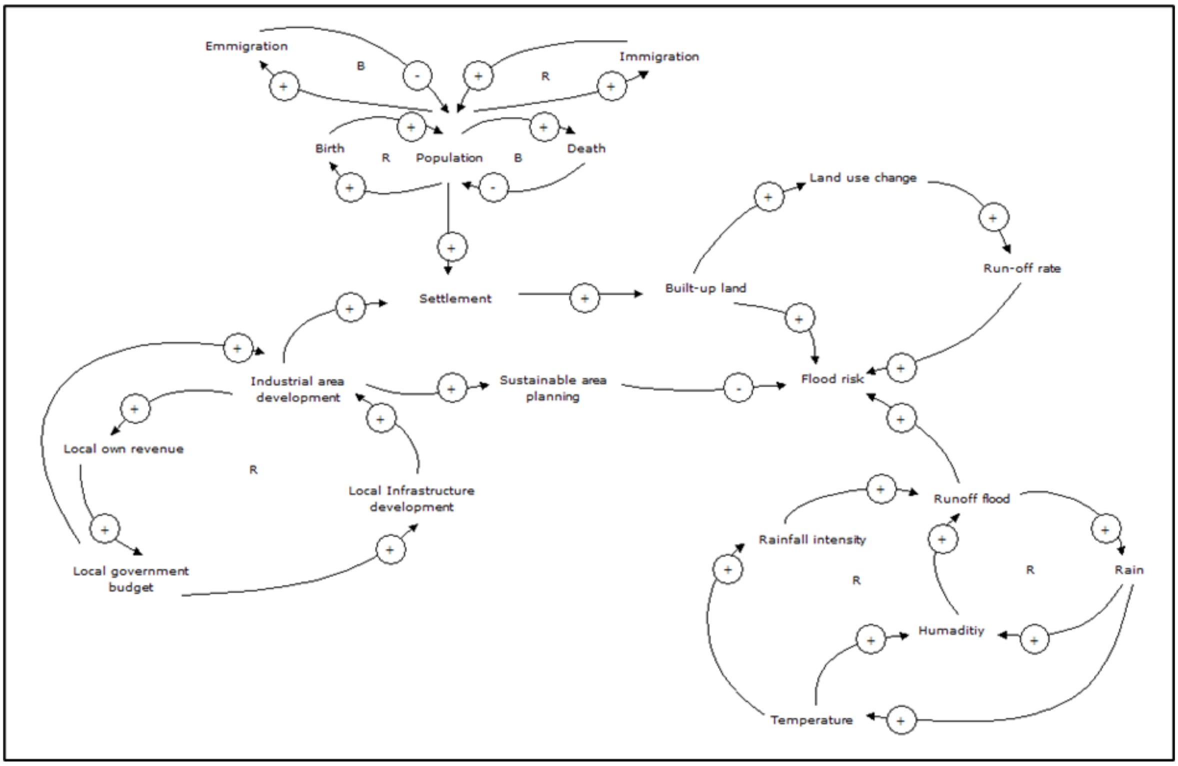

Figure 4. Causal Loop Diagram of Flood Disaster Risk Model in Industrial Area Planning (Sustainable Development in Industrial Areas in Karawang Regency, West Java Province)

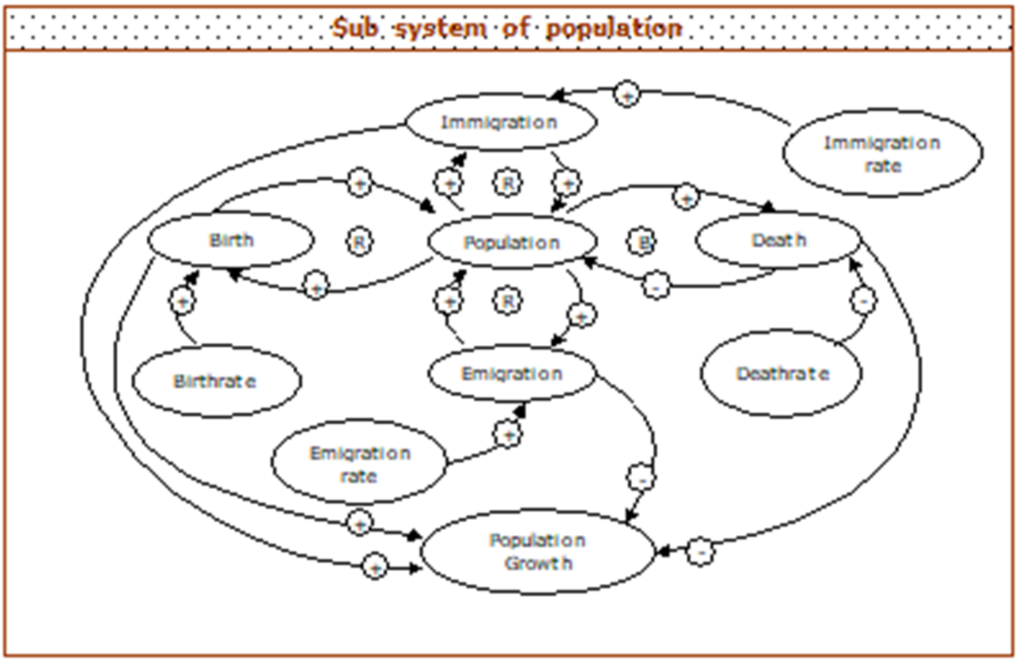

Figure 5. Sub System of Population on Flood Risk Model in Industrial Area Planning (Sustainable Development in Industrial Areas in Karawang Regency, West Java Province)
Source: Processed by authors (2021).

Figure 8 shows the Economy model in the industrial area of Karawang Regency. According to Hadi (2019), industrial activities in this region are likely to develop with assistance from foreign investment (PMA) and domestic investment (PMDN), which is a stimulant for the local gross domestic product (PDRB). This regency's regional budget is sourced from the regional allocation fund (DAK/DAU), local own-source revenue (PAD), and other income capable of reducing poverty and increasing the human development index (IPM).

Result and Discussion

The supervised analysis at the research locations is based on 7 classifications, namely water body, secondary forest, plantation, rice fields, industry, settlements, and road. The ArcGIS was used to determine the area and percentage of each land use/land cover in Telukjambe Barat and Telukjambe Timur, which started from 1989 to 2019. The following figures (Figure 9) is a Land Use/Land Cover (LULC) maps of Telukjambe Barat and Telukjambe Timur in 1989, 1999, 2009, and 2019.

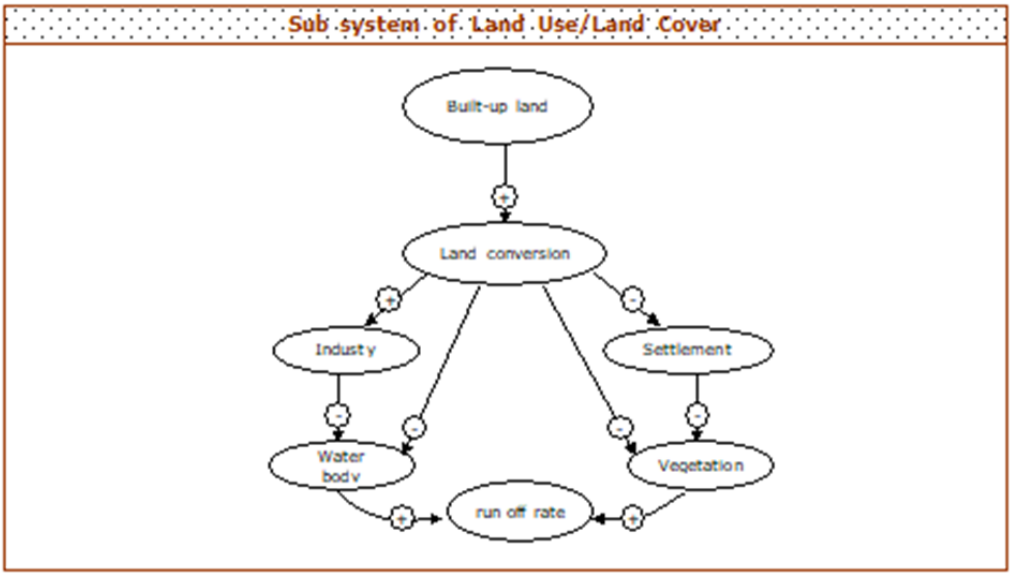

Figure 6. Sub System of Land Use/Land Cover on Flood Risk Model in Industrial Area Planning (Sustainable Development in Industrial Areas in Karawang Regency, West Java Province) Source: Processed by authors (2021).

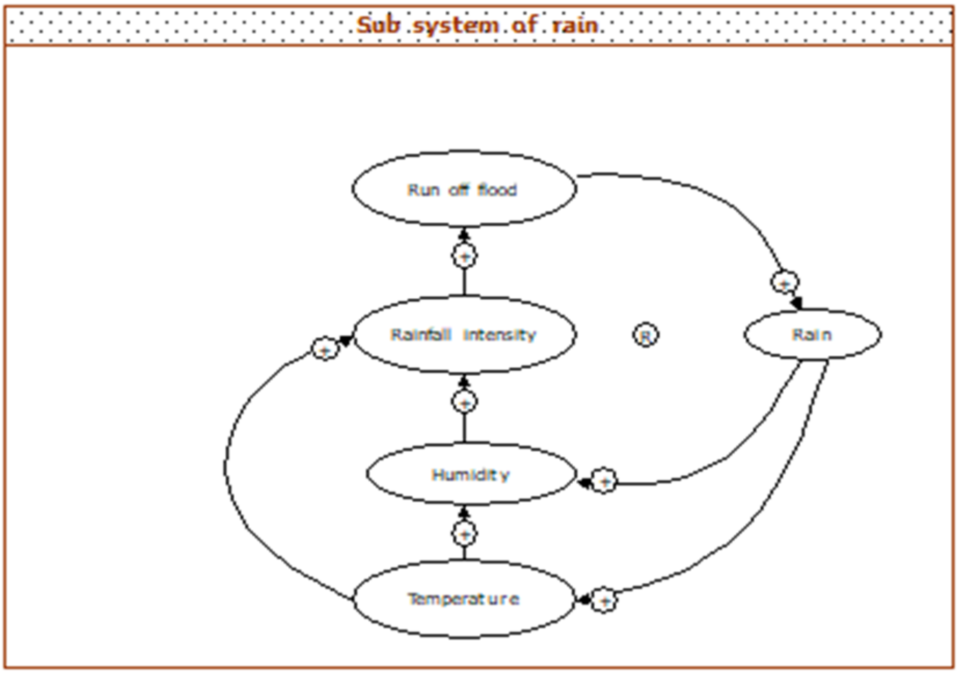

Figure 7. Sub System of Rain on Flood Disaster Risk Model in Industrial Area Planning (Sustainable Development in Industrial Areas in Karawang Regency, West Java Province) Source: Processed by authors (2021).

Land Use/Land Cover in Telukjambe Barat and Telukjambe Timur in 1989

Figure 9 (a) shows the supervised classification results on land use/land cover in the Telukjambe Barat and Telukjambe Timur obtained in 1989 was dominated by plantations area of 6,451.82 ha or 54.64%. Furthermore, both sub-districts had a rice field area of 3,396.51 ha or 28.76% of the total region, while the distribution of settlements was mostly discovered in the middle of the research locations.

The third land use/land cover involves settlements with 1,611.95 ha or 13.65% of the total region, while the distribution of settlements was discovered in the middle and northern parts of both sub-districts. Meanwhile, the smallest land use/land cover in both sub-districts in 1989 are the roads, with an area of 43.63 ha or 0.37% of the total region.

Land Use/Land Cover in Telukjambe Barat and Telukjambe Timur in 1999

The dominant land use/land cover in Telukjambe Barat and Telukjambe Timur in 1999 was plantations, with an area of 6,031.36 ha, which is 51.08% of the total region. This was followed by rice fields and settlements with areas of 3,267.65 ha or 27.67% and 1,768.31 ha or 14.98%, respectively. Meanwhile, the smallest was secondary forests, with an area of 35.11 ha or 0.30%, with limited distribution.

Land Use/Land Cover in Telukjambe Barat and Telukjambe Timur in 2009

Based on map 9 (c), the largest land use/land cover was a plantation, with an area of 5,462.17 ha or 46.26% of the total region. This was followed by rice fields and settlements with 3,015.21 ha or 25.54% and 2,085.12 ha or 17.66%, respectively. Meanwhile, the industry was mostly found in the middle of Telukjambe Barat and Telukjambe Timur Sub-Districts and towards the Southeast of Karawang Regency. The smallest land use/land cover was secondary forests, with an area of 29.51 ha or 0.25%.

Land Use/Land Cover in Telukjambe Barat and Telukjambe Timur in 2019

Figure 9 (d) shows that the largest land use/land cover was plantations, with an area of 4,551.14 ha or 38.54% of the total region. This was followed by rice fields and settlements with areas of 3042.14 ha or 25.76% and 2,201.34 ha or 18.64%, respectively. Meanwhile, the secondary forest had the smallest area at 0 ha or 0.00% compared to others.

Land Use/Land Cover Changes in Telukjambe Barat and Telukjambe Timur from 1989 to 2019

Land use/land cover in Telukjambe Barat and Telukjambe Timur experienced changes in the water body, secondary forest, plantation, rice field, industry, settlement, and road from 1989 to 2019, as shown in Table 2.

There was a yearly decrease in land use for plantation purposes in both sub-districts from 1989 to 2019, as shown in Figure 10. Land conversion is the main problem that causes land damage, increased frequency of floods, and sedimentation erosion at the bottom of the Citarum and Cibeet Rivers (JICA, 2015). According to Amalia (2015), there was a decrease in dryland farming, forest, paddy field, and water body, increasing the fishpond and built-up area from 1994 to 2004. From 2004 to 2014, the forest and paddy field experienced a decrease in dry farming, increased fishpond, and built-up area water bodies. The changing trend from 1994 to 2014 showed the tendency of paddy field conversion into a built-up area or into dry land, which then converted similarly. Suliman & Setiawan (2022) stated that agricultural land in Karawang Regency from 2009 to 2014 decreased by 8,639.84 Ha, and from 2014 to 2019, it

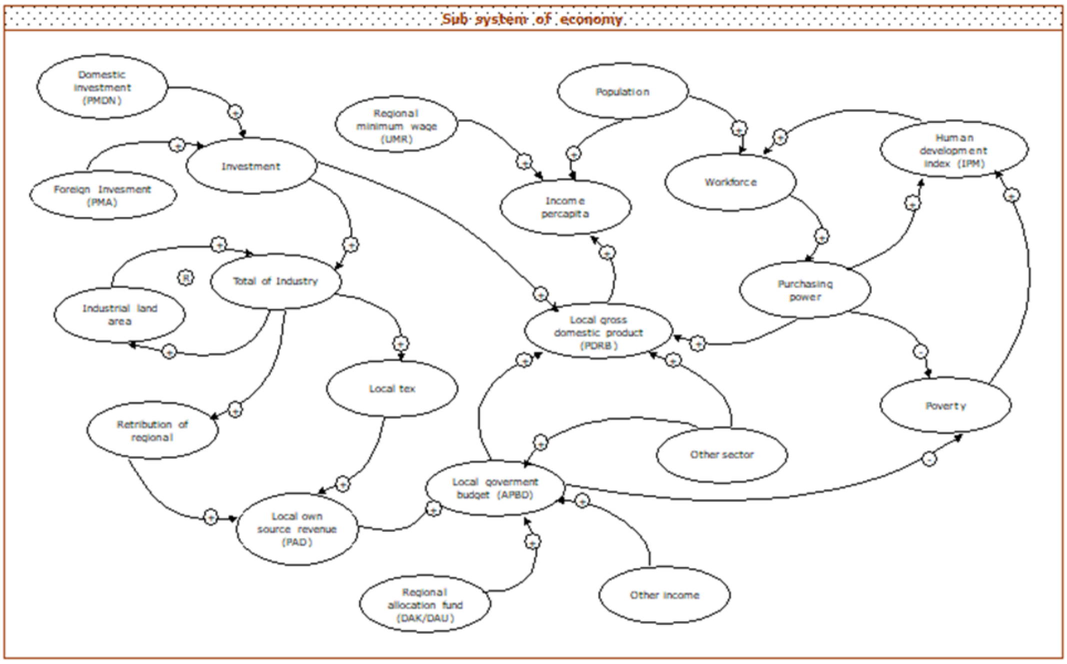

Figure 8. Sub System of Economy on Flood Disaster Risk Model in Industrial Area Planning (Sustainable Development in Industrial Areas in Karawang Regency, West Java Province)
Source: Hadi (2019). Modified by authors (2021).

Table 2. Land Use/Land Cover Area of Telukjambe Barat and Telukjambe Timur in 1989 - 2019

Land Use (Ha)	Year			
	1989	1999	2009	2019
Waterbody	402.45	191.84	227.92	252.33
Secondary forest	44.55	35.11	29.51	0
Plantation	6,451.82	6,031.36	5,462.17	4,551.14
Rice fields	3,396.51	3,267.65	3,015.21	3,042.14
Industry	85.97	469.94	944.28	1,717.26
Settlements	1,611.95	1,768.31	2,085.12	2,201.34
Road	43.63	43.63	43.63	43.63

Source: Processed by authors (2021).

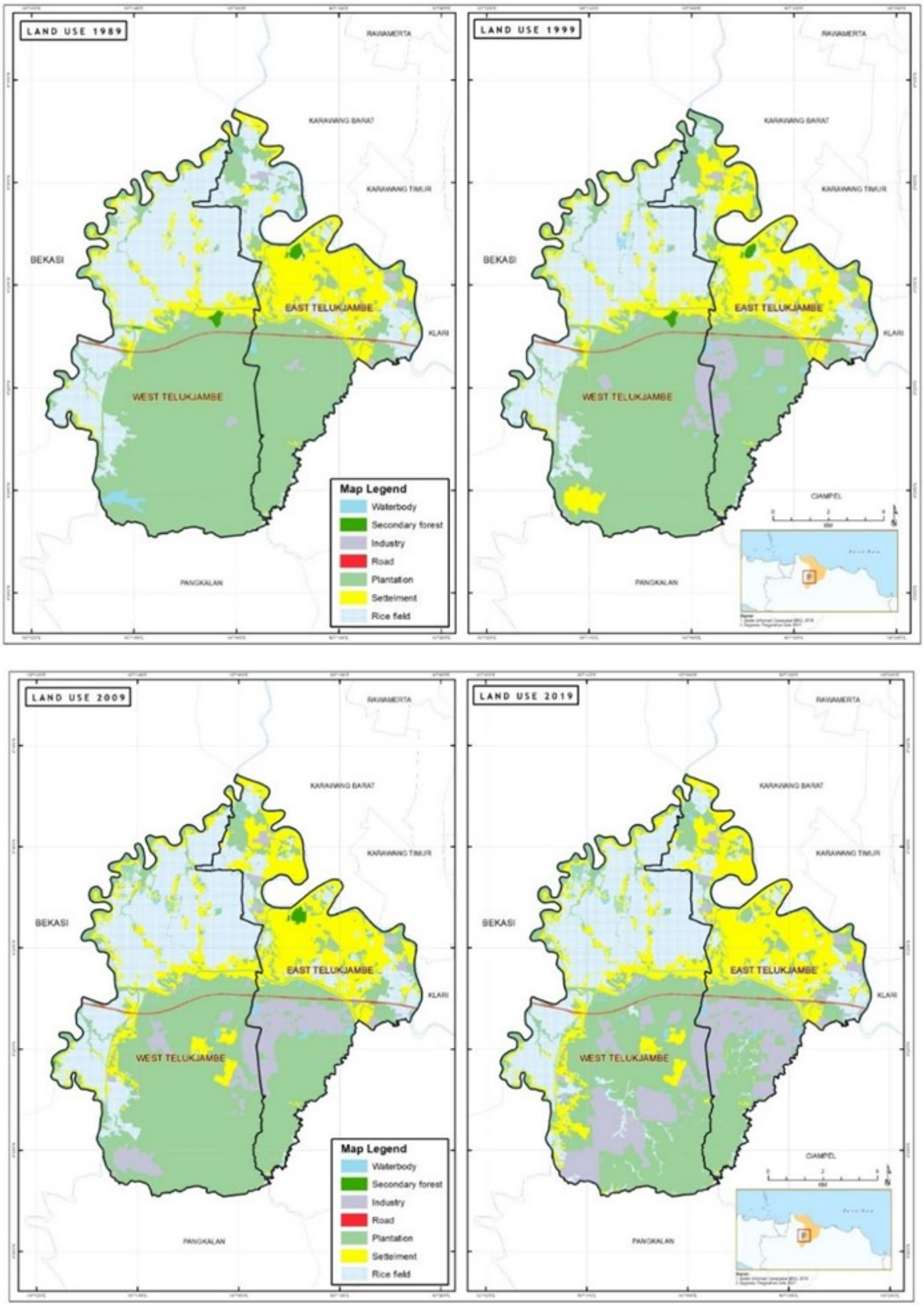

Figure 9. Land Use/Land Cover of Telukjambe Barat and Telukjambe Timur (a) in 1989, (b) in 1999, (c) in 2009, (d) in 2019
Source: Processed by authors (2021).

decreased by 7,706.93 Ha. The conversion of paddy fields over the past 10 years has been driven by an increase in land demand for settlements, commercial areas, and industrial activities.

Land Use/Land Cover Validation

The verification and validation processes were carried out to determine the land use or land cover classification level of truth. Figures from the validation stage are obtained after testing the accuracy of image interpretation results with field conditions. Furthermore, the number of test samples was calculated using the purposive sampling method and assisted by the archival recording of Google Earth images according to the existing research time.

According to Altman (1991) and Subiyanto & Suprayogi (2019), the stages of accuracy testing in 8 land use/land cover classifications use the overall accuracy calculation with a minimum limit of 75% and kappa with an accuracy value of 0-100% (Altman, 1991; Subiyanto & Suprayogi, 2019). The accuracy test of this research uses 57 sample points for 1989 and 1999 and 59 for 2009 and 2019 obtained from the results of purposive sampling. To sum, the Land Use/Land Cover validation in 1989, 1999, 2009, and 2019 are presented in Table 3.

The matrix analysis results filled in by Zah's Excel table obtained an overall accuracy value of 84.21%, 87.72%, 88.14%, and 88.14% in 1989, 1999, 2009, and 2019, respectively. Meanwhile, for the kappa accuracy, the figures

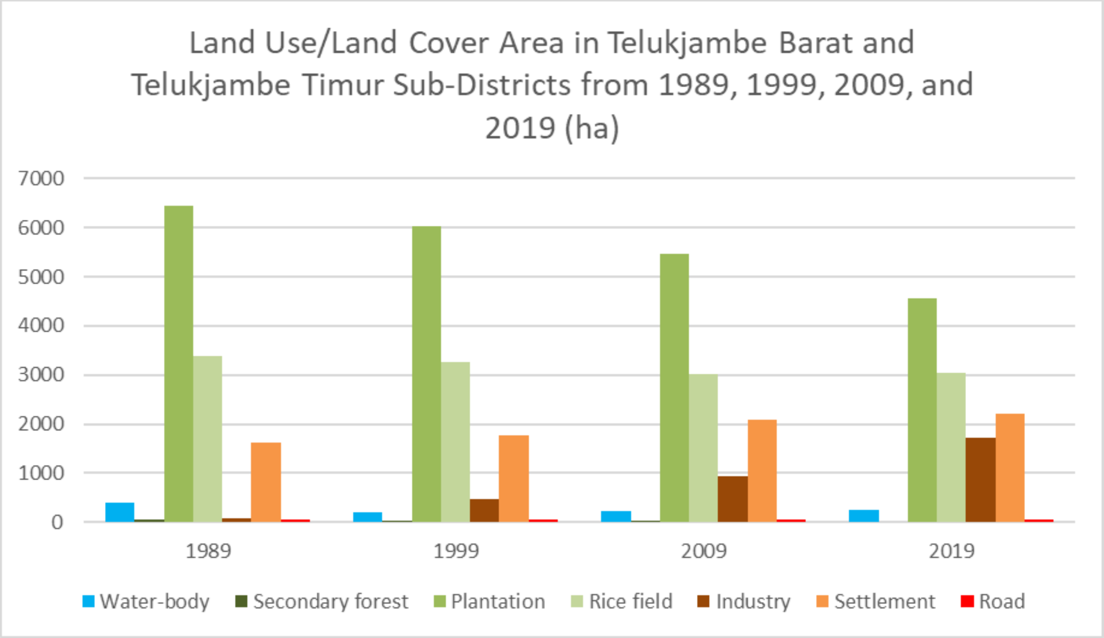

Figure 10. Graph of Land Use Area in Telukjambe Barat and Timur Sub-Districts from 1989, 1999, 2009, to 2019

Source: Processed by authors (2021).

Table 3. Land Use/Land Cover Validation

Validity	Years			
	1989	1999	2009	2019
Overall accuracy (%)	84.2105	87.7193	881356	88.13559
Kappa Coefficient (%)	81.9620	84.0336	88.7705	82.5409

Source: Processed by authors (2022).

Description:

> 81-100% (very good), 61-80% (good), 41-60% (currently), 21-40% (not good)

> 75% Figure can be accepted in research (Lapan, 2015)

were 81.96%, 84.03%, 88.66%, and 82.46% for 1989, 1999, 2009, and 2019, respectively. These results fall into the very good category. Therefore, they can be used for further analysis.

Land Use/Land Cover Projection Using Cellular Automata Model

The land use/land cover projection for 2031 is obtained by comparing changes between 2009 and 2019. The Cellular Automata (CA) modeling is shown in Figure 11.

The land use projection in the research area showed rapid development around the toll access with the formation of Industries and settlements. This research stated that the CA modeling in the Karawang Industrial Area was successfully conducted with an accuracy rate of relatively 85%. Its constraints occurred in the 2009 and 2019 land use classification sourced from Landsat 8 and the Ministry of Agrarian and Spatial Planning or National Land Agency of this Regency. Therefore, further research is recommended to include driving variables, such as a combination of land worth and capabilities and GRDP, to achieve higher accuracy and validation values. The distribution of the land use/land cover projection in Telukjambe Barat and Telukjambe Timur is depicted in Figure 12.

The ANN test in this research is used to obtain the smallest Minimum Validation Overall Error value, which is 0.1012. This method is preferred in land use modeling (prediction) research and validated using the kappa validation process. The results of land use projections were analyzed using the cellular automata method. Based on the calculation results, the kappa accuracy value obtained is more than 80%, which shows that land-use modeling can be used. The following figures (Figures 13 and 14) show Kappa Validation and ANN Test result graphics.

Survey and Field Questionnaire Results

This research also examines economic, social, and environmental factors in Karawang Regency, specifically in Telukjambe Barat and Telukjambe Timur Sub-districts. According to Mileti (1999), natural disaster management is related to fluctuations in the interaction between humans and their environment. Therefore, engineering resilience also applies to community resilience.

The questionnaires were distributed to 400 respondents from both sub-districts to obtain relevant information regarding community perceptions on the impact of industrial area development on land-use changes and economic losses due to the flood disaster. The following results were obtained based on the questionnaire analysis.

Figure 16 shows the report of economic losses of the community due to the flood disaster. Most respondents in both sub-districts reported that floods negatively impacted

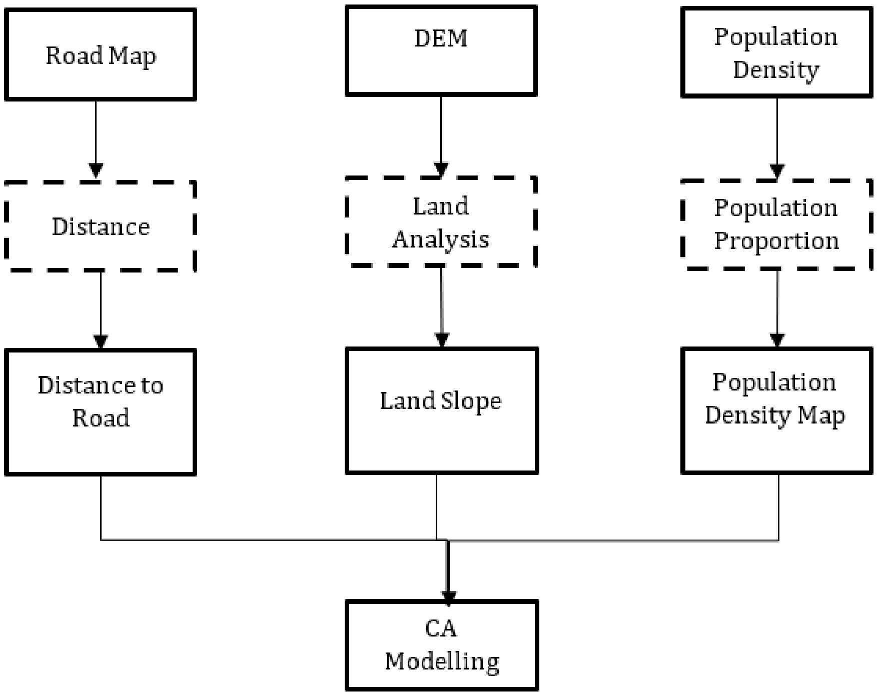

Figure 11. Cellular Automata Modeling
Source: Processed by authors (2021).

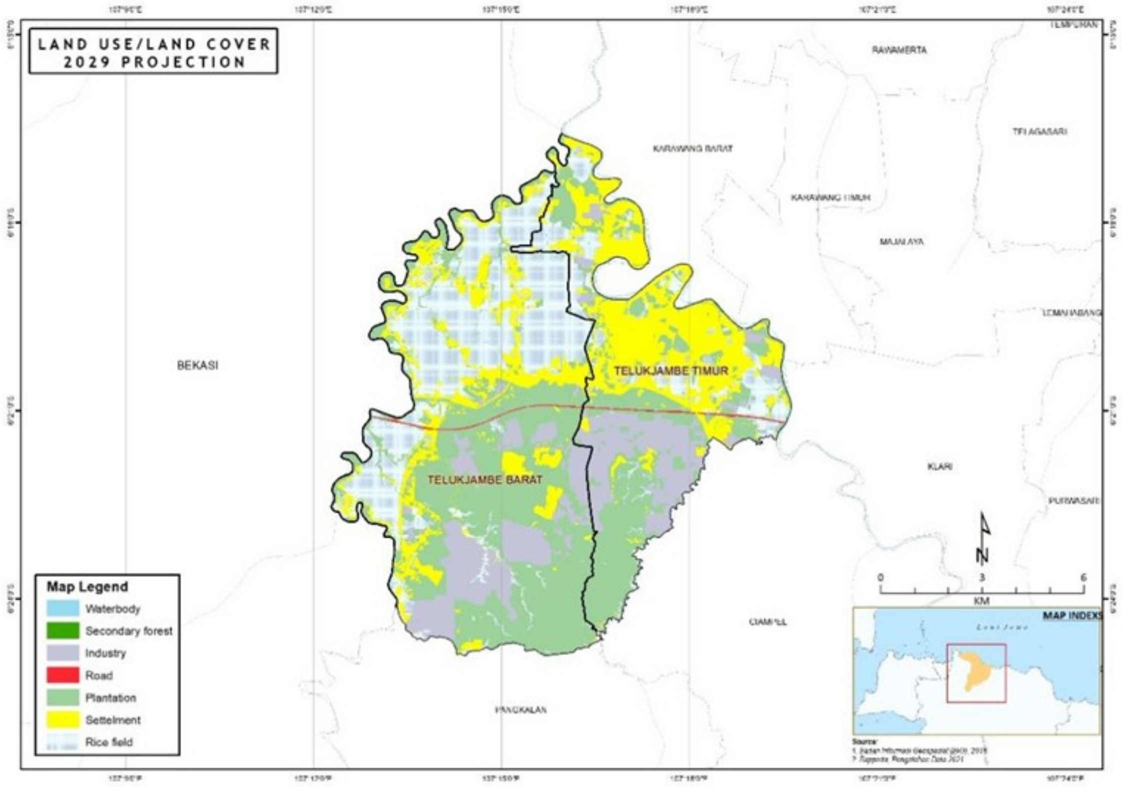

Figure 12. Land Use/Land Cover 2029 Projection
Source: Processed by authors (2022).

the economy because they experienced material losses of less than IDR 1,000,000. In addition, this disaster led to damaged houses, goods, and loss of other valuables. According to Riadi & Gaol (2018), high risk areas prone to flooding are Batujaya, Cilebar, Karawang Barat, Pakisjaya, Pedes, Rawamerta, Rengasdengklok, Telukjambe Barat, Telukjambe Timur and Tempuran Sub-Districts.

Validity and Reliability Tests

Validity Test

The validity test is used to determine the reliability and validity level of the measuring instrument used. The test was carried out on 30 respondents using the IBM SPSS Statistics 23 program. The questionnaires are presumed to be valid, supposing the questions can reveal specific

Figure 13. Kappa Validation
Source: Processed by authors (2022).

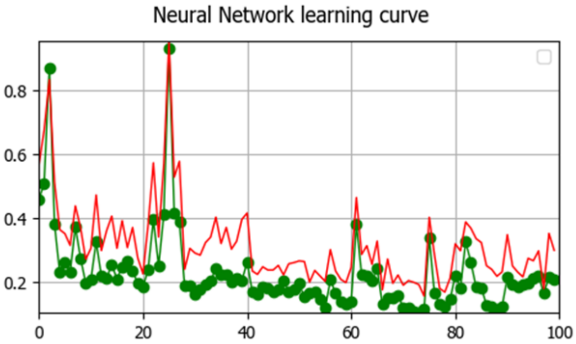

Figure 14. ANN Test Result
Source: Processed by authors (2022).

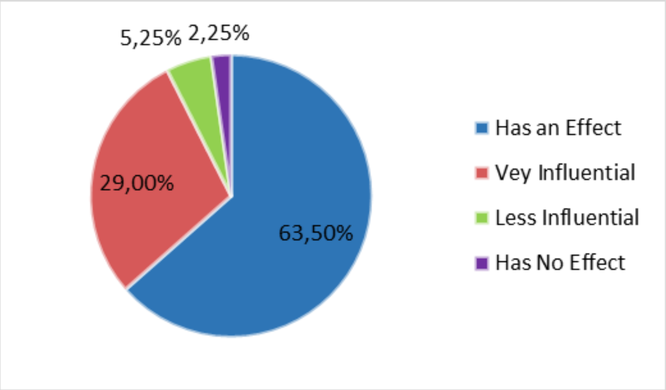

Figure 15. Diagram of Community Perception on the Effect of Industrial Area Development on Land Use/Land Cover Changes
Source: Processed by authors (2021).

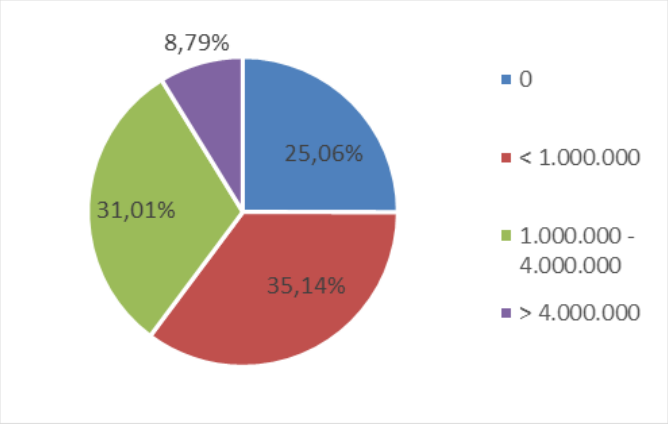

Figure 16. Diagram of Economic Losses of the community due to the flood disaster
Source: Processed by authors (2021).

Table 4. Reliability Test Results

Field	Cronbach's Alpha	Criteria
Environmental	0.801	Reliable
Economic	0.819	Reliable
Social	0.817	Reliable
Flood Impact	0.724	Reliable

Source: Processed by authors (2021).

relevant facts. The SPSS output used to test the validity of each component of the environmental, social, and economic factor shows valid results because of the value of r-count > r-table.

Reliability Test

This test was calculated using SPSS with Cronbach's Alpha statistical test, which is presumed to be reliable, supposing it is more significant than 0.60. Based on Table 4, the r-count is greater than 0.6 with a significance level of 5%, indicating the questionnaire for the environmental, economic, social, and flood impact fields is reliable.

Multiple Regression Test

This test was conducted to determine the effect of environmental (X_1), economic (X_2), and social (X_3) independent variables on flood impact loss (Y). The following regression model was obtained

$$Y = 24{,}932 + 0{,}532X_1 + 0{,}015X_2 + 0{,}188X_3 \qquad (1)$$

Furthermore, the determination coefficient from the regression equation is 0.556, which simply means that the combinations of environmental, economic, and social factors have an effect of 55.6% on the flood impact loss. Other external variables influence the remaining 44.4%.

Correlation Test

The 3 correlations between the independent and dependent variables carried out in this research are as follows:

1. Correlation between Flood Impact and Environmental Factor
2. The flood impact and environmental factor have a strong relationship because it has a Pearson Correlation of 0.731 and a positive relationship direction. This means that when environmental factors, such as damage (X_1) increase, the impact of flooding felt by the community (Y) rises and vice versa.
3. Correlation between Flood Impact and Economic Factor. The flood impact and economic factor have a weak correlation because it has a Pearson Correlation of 0.429 and a positive relationship direction. This means that when economic factors, such as material losses (X_2) increase, the impact of flooding on the community (Y) rises and vice versa.
4. Correlation between Flood Impact and Social Factor. The flood impact and environmental factor have a strong relationship because it has a Pearson Correlation of 0.656 and a positive relationship direction. This means that when social factors, such as a sense of

caring and poor communication (X_3) increase, the impact of flooding felt by the community (Y) rises and vice versa.

Conclusion

In conclusion, the disaster risk model is closely related to the social, economic, and environmental realms. These include sub-model of population, land use, flood risk, and industrial areas that act as hazard and vulnerability factors. The integrated spatial plan acts as a capacity factor, which reduces the flood disaster risk. The conversion of built-up land, population growth, and high rainfall intensity increase the hazard and vulnerability factors, leading to a rise in flood risk.

The analysis results showed a decrease in water bodies, secondary forests, plantations, and rice fields at the research locations from 1989 to 2019 due to the growth of industrial areas and settlement in the South, Southeast, and Southwest of Telukjambe Barat and Telukjambe Timur Sub-District. Within 30 years, these industrial areas expanded to the plantation and the water body regions.

Based on the questionnaires distributed to 400 respondents, 63.5% agreed that the development of industrial areas affects land use/land cover changes. In contrast, 74.94% experienced a negative impact of losing assets ranging from less than IDR 1,000,000 to more than IDR 4,000,000.

The regression model shows that environmental, economic, and social factors affect the flood impact loss by 55.6%, while external variables influence the remaining 44.4%. The close connection between the independent (environmental, social, and economic factors) and dependent (flood impact) variables proves that the flood impact and environmental factor have the strongest relationship because it has the highest Pearson Correlation of 0.731.

The Cellular Automata application tools and land use/ land cover projection show the expansions of settlements around the industrial area, adjoined rice fields, and plantations in the North of Telukjambe Barat and Telukjambe Timur. This result is also supported by the Kappa coefficient, more than 0.978. The linkage between environmental, social, and economic factors within the disaster risk model implied an integrated spatial plan approach as an ecological perspective can be used to realize sustainable development in industrial areas in Karawang.

References

Abdurachman, A. A. (2010). Perubahan penggunaan lahan pertanian menjadi daerah terbangun di Kabupaten Karawang tahun 1984 dan 2008. Skripsi, Universitas Indonesia. Accessed from http://lontar.ui.ac.id/detail?id=20181781&lokasi=lokal

Aderogba, KA. (2012). Qualitative Studies of Recent Floods and Sustainable Growth and Development of Cities and Towns in Nigeria. International Journal of Academic Research in Economics and Management Sciences, 1(3), 1-25.

Adipraja, P. F. E., & Sulistyo, D. A. (2018). Pemodelan Sistem Dinamik untuk Prediksi Intensitas Hujan Harian di Kota Malang. Jurnal Ilmiah Teknologi Informasi Asia, 12(2), 137-146.

Ahmad, R. (2016). A Study of Relationship between Liquidity and Profitability of Standard Chartered Bank Pakistan: Analysis of Financial Statement Approach. Global Journal of Management and Business Research: C Finance, 16 (1), 77-82.

Amalia, I. R. (2015). Modeling of Land Use Change of Paddy Field in Karawang Regency Using Cellular Automata-Markov Chain (Doctoral dissertation, Bogor Agricultural University (IPB)).

Akbari, F. R. (2016). Evaluasi Pengaruh Koreksi Atmosferik Dalam Algoritma Untuk Perhitungan Total Suspended Solid Menggunakan Citra Satelit Landsat 8 (Doctoral dissertation, Institut Teknologi Sepuluh Nopember Surabaya).

Badan Penanggulangan Bencana Daerah (BPBD) Karawang. (2021). Data Kejadian Banjir 2014 – 2020.

Badan Pusat Statistik (BPS). (2017). Kabupaten Karawang Dalam Angka 2017. https://karawangkab.bps.go.id/publication/2017/08/17/258839c82b4aaf001be0f08f/kabupaten-karawang-dalam-angka-2017.html

Chen, Y., Liu, R., Barrett, D., Gao, L., Zhou, M., Renzullo, L., & Emelyanova, I. (2015). A spatial assessment framework for evaluating flood risk under extreme climates. Science of the Total Environment, 538, 512-523.

Cooley, A., & Chang, H. (2017). Precipitation intensity trend detection using hourly and daily observations in Portland, Oregon. Climate, 5(1), 10.

Ekadinata, A., Dewi, S., Hadi, D., Nugroho, D., & Johana, F. (2008). Sistem informasi geografis untuk pengelolaan bentang lahan berbasis sumber daya alam. World Agroforestry Centre: Bogor.

Eriyatno. (2012). Ilmu Sistem: Meningkatkan Mutu dan Efektivitas Manajemen. Bogor (ID): IPB Press.

Dachlan, D., & Rosmarini, N. (2016). Karawang Tantangan Si Lumbung Padi. http://citarum.org/info-citarum/berita-artikel/1046-karawang-tantangan-si-lumbung-padi.html

Faisol, A. (2009). Identifikasi dan klasifikasi peruntukan lahan menggunakan Citra ASTER. *Media Teknik Sipil*. (IX):1 – 8.

GISGeography. (2021). Landsat 8 Bands and Band Combinations. Accessed on 7th January 2021, from https://gisgeography.com/landsat-8-bands-combinations/

Guan, D., Li, H., Inohae, T., Su, W., Nagaie, T., & Hokao, K. (2011). Modeling urban land use change by the integration of cellular automaton and Markov model. Ecological modelling, 222(20-22), 3761-3772.

Hadi, A. (2019). Model Dinamik Pengembangan Kawasan Industri Berkelanjutan Di Wilayah Perkotaan Gresik Jawa Timur (Doctoral dissertation, Universitas Brawijaya).

Irene, P. L. (2015). Farmland conversion in Karawang, Indonesia: discourse analysis. Faculty of Bioscience Engineering, Universiteit Gent.

Janti, N. (2019). Lumbung Padi yang Jadi Kawasan Industri. *https://historia.id/ekonomi/articles/lumbung-padi-yang-jadi-kawasan-industri-PdlMk/page/1*

Japan International Cooperation Agency (JICA). (2015). Natural Disaster Risk Assessment and Area Business Continuity Plan Formulation for Industrial Agglomerated Areas in the ASEAN Region. *Country Report.*

Johnson, B. A., Estoque, R. C., Li, X., Kumar, P., Dasgupta, R., Avtar, R., & Magcale-Macandog, D. B. (2021). High-resolution urban change modeling and flood exposure estimation at a national scale using open geospatial data: A case study of the Philippines. Computers, Environment and Urban Systems, 90, 101704.

Lembaga Penerbangan dan Antariksa Nasional (LAPAN). (2015). Pedoman Pengolahan Data Satelit Multispektral Secara Digital Supervised Untuk Klasifikasi. Jakarta: Pusat Pemanfatan Penginderaan Jauh Lembaga Penerbagnan dan Antariksa Nasional.

Liao, K.-H. (2012). A Theory on Urban Resilience to Floods—A Basis for Alternative Planning Practices. *Ecology and Society*, *17* (4).

Luo, K., & Zhang, X. (2022). Increasing urban flood risk in China over recent 40 years induced by LUCC. Landscape and Urban Planning, 219, 104317.

Mahmoud, S. H., & Gan, T. Y. (2018). Urbanization and climate change implications in flood risk management: Developing an efficient decision support system for flood susceptibility mapping. Science of the Total Environment, 636, 152-167.

Mileti, D. (1999). Disasters by design: A reassessment of natural hazards in the United States. Joseph Henry Press.

Mustafa, A., Bruwier, M., Archambeau, P., Erpicum, S., Pirotton, M., Dewals, B., & Teller, J. (2018). Effects of spatial planning on future flood risks in urban environments. Journal of environmental management, 225, 193-204.

Pandey, S. S., Cockfield, G., & Maraseni, T. N. (2013). Major drivers of deforestation and forest degradation in developing countries and REDD+. International Journal of Forest Usufructs Management, 14(1), 99-107.

Pielke, R. A., Bluestein, H. B., Enfield, D. B., Wells, N. C., Cenedese, C., Davies, R., Waggoner, P. E., Gentili, J., Lamb, H. H., Smith, P. J., Arnfield, A. J., Mason, B. J., Krishnamurti, T. N., Hayden, B. P., & Loewe, F. P. (2022). Atmospheric humidity and precipitation. Retrieved February 28, 2022, from https://www.britannica.com/science/climate-meteorology/Atmospheric-humidity-and-precipitation

Riadi, B. & Gaol, Y. A. L. (2018). Spatial Modeling of Flood Risk in Karawang. Advances in Science, Technology, and Engineering System Journal, 3(5): 200-206.

Sakti, B., & Ikhwan, J. (2019). Model Sistem Dinamik Ketersediaan Lahan Terbangun di Provinsi Bengkulu. J. Ekon. dan Kebijak. Publik, 2(2), 1-12.

Septiani, R., Citra, I. P. A., & Nugraha, A. S. A. (2019). Perbandingan metode supervised classification dan unsupervised classification terhadap penutup lahan di Kabupaten Buleleng. Jurnal Geografi: Media Informasi Pengembangan Dan Profesi Kegeografian, 16(2), 90-96.

Seto, K. C., Fragkias, M., Güneralp, B., & Reilly, M. K. (2011). A meta-analysis of global urban land expansion. PloS one, 6(8), e23777.

Setyowati, D., Munibah, K., & Hadi, S. (2015). Dinamika Perubahan Penggunaan Lahan Industri Kaitannya Dengan PDRB Sektor Industri di JABODETABEK. *Jurnal Ilmu Tanah dan Lingkungan*, 17(2), 83-89.

Siagian, F. (2011). Kajian Pelayanan Rute Transportasi Angkutan Kota dan Mobilitas Penduduk Menuju Pusat-pusat Pelayanan di Kota Karawang Provinsi Jawa Barat. Skripsi thesis, Universitas Muhammadiyah Surakarta.

Sopyan, A. (2014). Upaya Mempertahankan Kabupaten Karawang Sebagai Lumbung Padi Nasional. http://repository.unisba.ac.id/handle/123456789/228

Subiyanto, S., & Suprayogi, A. (2019). Modeling And Spatial Analysis Of Change Settlement And Fair Market Land Price Using Markov Chain Model In Banyumanik District. KnE Engineering, 278-290.

Suliman, S., & Setiawan, Y. (2022). Assessing the paddy fields conversion using optical satellite imageries: A case study in Karawang Regency, West Java. In IOP Conference Series: Earth and Environmental Science (Vol. 950, No. 1, p. 012092). IOP Publishing.

Tian, L., Ge, B., & Li, Y. (2017). Impacts of state-led and bottom-up urbanization on land use change in the peri-urban areas of Shanghai: Planned growth or uncontrolled sprawl?. Cities, 60, 476-486.

Twigg, J. (2015). Disaster Risk Reduction. (New Edition 2015). London: Humanitarian Policy Group.

Widiatmaka., Munibah, K., Firmansyah, I., & Santoso, P. B. K. (2013). Evaluasi Kesesuaian Lahan untuk Padi Sawah Menggunakan Automated Land Evaluation System di Sentra Produksi Padi Karawang Bagian Utara, Provinsi Jawa Barat. Prosiding Seminar Hasil-Hasil PPM IPB. (II):476-492.