Journal of Natural Resources and Environmental Management
12(2): 268-280. http://dx.doi.org/10.29244/jpsl.12.2.268-280
E-ISSN: 2460-5824
http://journal.ipb.ac.id/index.php/jpsl

Contributing factor influencing flood disaster using MICMAC (Ciliwung Watershed Case Study)

Dwi Ariyani[ae], Mohammad Yanuar Jarwadi Purwanto[b], Euis Sunarti[c], Perdinan[d]

[a] Postgraduate Student of PSL Study Program, Graduate School, IPB University, Darmaga Bogor Campus IPB, 16680, Indonesia
[b] Department of Civil and Environmental Engineering, IPB University, Darmaga Bogor Campus IPB, 16680, Indonesia
[c] Department of Family and Consumer Sciences, Faculty of Human Ecology, IPB University, Darmaga Bogor Campus IPB, 16680, Indonesia
[d] Department of Geophysics and Meteorology, Faculty of Mathematics and Natural Sciences, IPB University, Darmaga Bogor Campus IPB, 16680, Indonesia
[e] Civil Engineering Study Program, Pancasila University, Srengseng sawah, Jagakarsa, South Jakarta City, Jakarta 12640

Article Info:
Received: 24 - 03 - 2022
Accepted: 13 - 04 - 2022

Keywords:
Dependence, flood variable, key variable, MICMAC

Corresponding Author:
Dwi Ariyani
Natural Resources and Environmental Management Study Program, Graduate School, IPB University;
Tel. +6285216157961
Email: dwi.ariyani@univpancasila.ac.id

Abstract. *Flood disaster is the most common disaster in Indonesia. Flood events continue to increase and occur almost every year during the rainy season, on average, caused by extreme rainfall above 100 mm. With the number of losses increasing every year, there are many factors that affect one of the causes of flooding is human activities resulting in changes in land use in the form of settlements and agricultural land. This paper aims to present a conceptual reference from the implementation results using software assistance to determine the level of influence and dependent variables. The method used to assess the most influential factors on flood events, especially in the Ciliwung watershed, is by using Cross-Impact Matric Multiplication Applied to Classification (MICMAC). From the 11 contributing factors analyzed based on the Matrix of Direct Influence (MDI) and Matrix of Indirect Influence (MII). it is known that rainfall and distance from the river are the variables that have the most influence. While the variables with the greatest dependence based on MDI and MII are land cover, slope, population density, and river waste, with institutions experiencing a larger variable displacement compared to other variables. The results of the identification of these contributing factors can be used by stakeholders to be careful of each factor as input in anticipating influencing factors.*

How to cite (CSE Style 8th Edition):
Ariyani D, Purwanto MYJ, Sunarti. E, Perdinan. 2022. Contributing factor influencing flood disaster using MICMAC (Ciliwung Watershed Case Study). JPSL **12**(2): 258-280. http://dx.doi.org/10.29244/jpsl.12.2.268-280.

INTRODUCTION

Flood disaster is one of the most serious disasters that occur all over the world, because flooding can be considered as one of the most destructive natural hazards. In addition to physical damage and financial losses, flooding can result in loss of human life, in Indonesia, which is a tropical country with two seasons, namely the rainy season and the dry season, almost every year floods occur in several big cities in Indonesia. According to the National Disaster Management Agency (BNPB) in 2021, floods occurred 1 794 times, the most number one compared to extreme climates (1 577 times) and landslides (1 321 times) (BNPB, 2022). It is necessary to have a better understanding of the characteristics of floods and the contributing factors that affect the potential for flooding, this is necessary in effective management of water resources to minimize the risk of a flood disaster. One of the areas that are regularly flooded every year is the Ciliwung Watershed (DAS). The Ciliwung River is the largest area that affects flood events in Jakarta, Depok, and Bogor. The length of the Ciliwung River flow starts from its upstream in the Gunung Gede-Pangrango area (Bogor Regency) to its downstream area in the Pluit area (North Jakarta), along 129 km This makes the Ciliwung river an important factor and has a major influence on the occurrence of flooding in the area. In general, climate change, human activities and the topography of an area are identified as one of the factors causing flooding.

There are many factors that cause flooding, in this study using 11 factors were analyzed using the MICMAC method, including rainfall, anthropogenic climate change, increasing the frequency and magnitude of extreme rainfall events as a cause of flood disasters. (Yilmaz *et al.*, 2014; Bian *et al.*, 2020), rainfall is included in the hazard component which is a dynamic factor that can change (Nugroho, 2008). Besides that, the topographic factors of an area affect the occurrence of flood hazards in an area, the digital elevation model (DEM) is one source that is widely used to obtain information about topographical factors related to flood hazard mapping (Ajim *et al.*, 2020; Christian *et al.*, 2020). Meanwhile the characteristics of a catchment area, such as soil moisture and slope, also play a role in modulating the severity of flooding, and severe flooding may occur in cases where soil conditions and slopes are less than 8% (Ajim *et al.*, 2020; Titley *et al.*, 2021). Another factor is land cover change, increasing human population demands more use of earth's resources, especially land resources, in this process it will decrease the retention capacity of soil moisture resulting in more surface runoff and therefore, more sudden flooding (Panahi *et al.*, 2010; Arifasihati and Kaswanto, 2016). Meanwhile, other factors such as garbage that is thrown carelessly into the river will hinder the flow of water from upstream of the river with the condition of nearby settlements from the river increasing the potential for flooding caused by overflowing of the river because it cannot accommodate the higher discharge (Sholihah *et al.*, 2020).

Infrastructure is one of the solutions in dealing with floods, but infrastructure has an environmental impact and increases the risk of flooding elsewhere. Moreover, the infrastructure approach alone does not address the main causes of flooding, which are believed to be a combination of reduced water catchment areas and high rainfall intensity (Shi, 2020). Early warning system factors in detecting a disaster and monitoring a hazard (Perera *et al.*, 2019) can reduce the incidence of disasters when applied properly. However, Indonesian institutions do not yet have adequate rules and instruments for designing cities that are safe from the threat of flooding, both from spatial planning, drainage systems, or wastewater management to return to the ground. Furthermore, institutional issues that need more attention are coordination between agencies with an interest in flood prevention and management (Sunarharum, 2021).

MICMAC analysis is used for analytical integration of parts of the system to identify clause feedback loops (either direct or indirect) between variables, which can be useful in improving the dynamics of analysis for future scenarios (Veltmeyer and Sahin, 2014; Ambrosio-albala and Delgado, 2008; Paulus and Fauzi, 2017). Research conducted in Tabriz City using MICMAC to analyze the factors involved in the development of urban green space with a systematic and structural approach and extract the most important factors for optimal urban green space development using the relationship between these factors (Teimouri and Hodjati, 2017). Adapting prospective structure analysis also needs to be carried out to strengthen sustainable management and capacity building in the context of community-based natural resource management (Delgado-serrano *et al.*, 2016; Ahmed dan Saleh, 2009). Research conducted on the North Coast of Central Java Province, Indonesia, to analyze the interest of stakeholders in relation to reducing flood risk was carried out using the MICMAC method (Isa *et al.*, 2019). In other countries, such as Colombia, it is possible to define strategic variables that will guide its strengthening in 2020 in presenting the conceptual techniques and results of applying MICMAC to determine the level of influence and dependence of variables (Benjumea-arias *et al.*, 2020).

METHOD

Location and Research Time

This research was conducted on the Ciliwung River, which passes through Bogor Regency, Bogor City, Depok City, South Jakarta, East Jakarta, to the Jakarta Bay, which has an area of 386 km^2. For a complete map of the study location, see Figure 1 below.

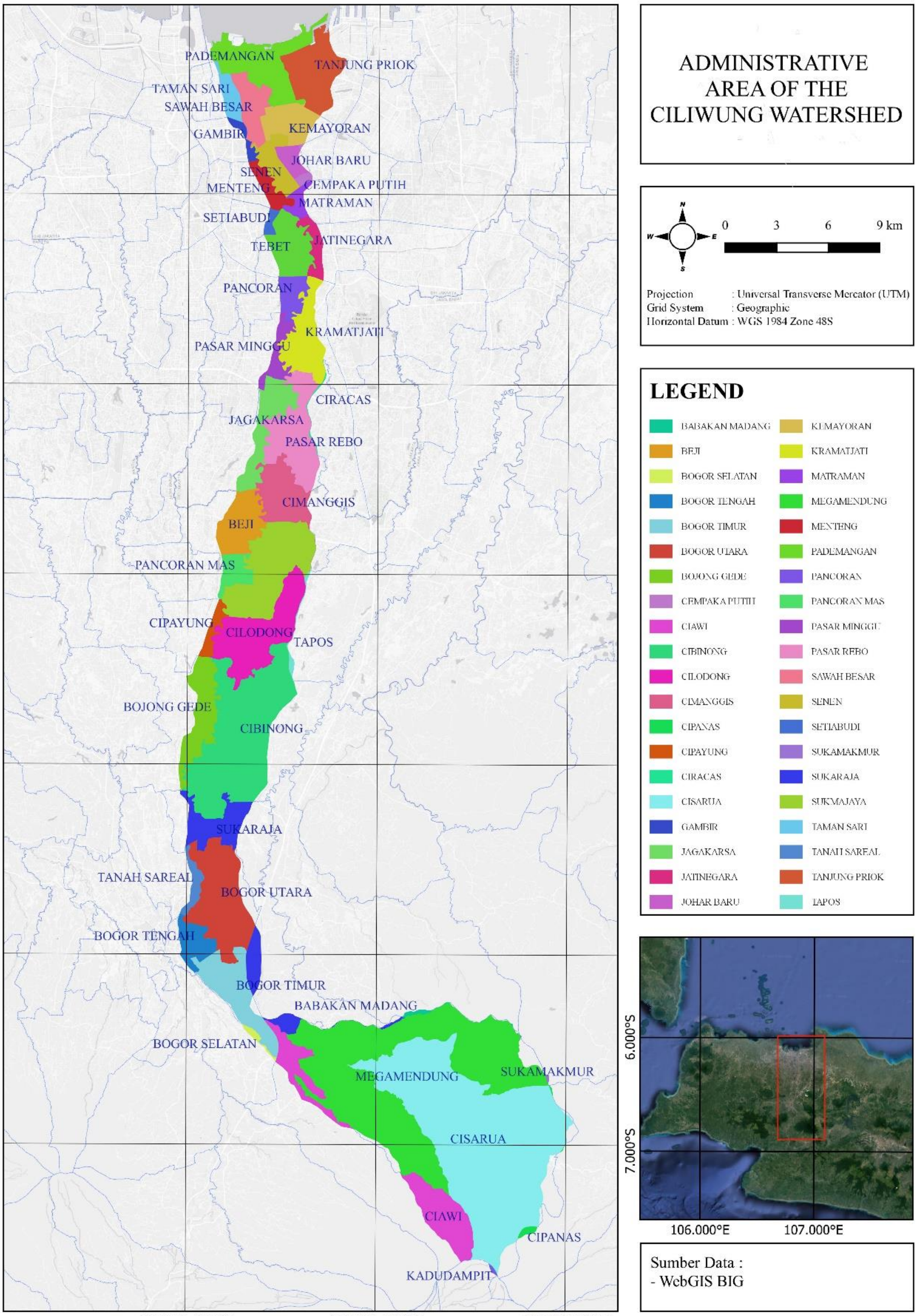


Figure 1 Ciliwung Watershed administration map

Method of Collecting Data

Literature search was carried out using online databases and search engines. The review includes published journals and conference papers identified from scimago and google scholar as well as reports published by organizations such as the World Meteorological Organization, government agencies, and traceable reports identified via online search (Google). Limitation of time period with a span of five to ten years. In conducting a literature review, we look for factors that contribute to the flood disaster. Primary data is obtained from the opinions of experts, using questionnaires and in-depth interviews, research flowchart can be seen in figure 2 below.

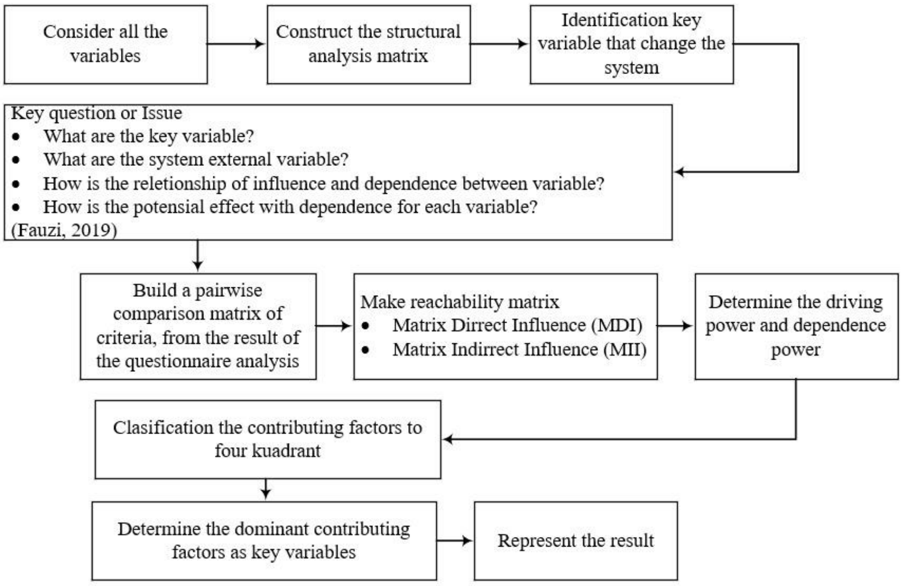


Figure 2 Research flowchart

Data Analysis Method

The method of analysis in this study is a quantitative method using software (MICMAC Software), by describing the results of the analysis based on the influence factor of each variable. MICMAC software is used to map variables to determine the relationship between variables, which is used to identify important factors that cause flooding. The MICMAC approach relies on analytical thinking to solve problems through systems. Therefore, MICMAC begins by asking questions, then identifying internal and external variables, and at the next stage, MICMAC analyzes the relationship between variables and the weight of the relationship according to the fluidity and level of dependence between variables (Fauzi, 2019). MICMAC helps identify the main variables that are important to the system and depend on it, MICMAC results can map the relationship between variables and the correlation of these variables in explaining the system, and reveal causal relationships of the system (Bashir dan Ojiako, 2020).

In MICMAC, the variables are grouped into four quadrants based on the category of dependence and influence. Analysis with MICMAC was carried out to obtain variables that influence the occurrence of flooding in the form of influence variables, relay variables, depending variables and Autonomous Variables, where the influence variable is a variable that has a large influence on other quadrants, but is less likely to be affected by other variables. Relay Variable (Intermediate Variable), which is a variable that has a big influence on the problem but at the same time it also has a high dependence on other variables. Dependent variables are variables that depend a lot on other variables, but have little effect. While the Autonomous Variable is a variable that depends a lot on other variables, but these variables do not have much influence or influence other variables. The factors used in the MICMAC analysis in this research are grouped into several dimensions, namely the dimensions of hazard, vulnerability and capacity, which can be seen in Table 1.

Table 1 Contributing factor variable

Dimensions	Variable Factors Causing Flood Disaster	Short Label
Hazard	Rainfall	Rainfall
	Elevation	Elevation
	Slope	Slope
	Land cover	Land cover
	Soil type, ability to infiltrate	Soil
	Distance from river	River dist
Vulnerability	Garbage in the river	Garbage
	Population density	Population density
Capacity	Infrastructure development such as drainage system	Infras
	Institutional rules	Institutional
	Early warning system	EWS

The scale in MIC-MAC uses a scale of 0 to 3 and P, where: 0 = no influence; 1 = weak influence; 2 = moderate influence; 3 = strong influence; P = potential influence

RESULT AND DISCUSSION

The matrix entry in Table 3 comes from Table 2, which shows the impact of each of the 121 paired connections identified by the experts based on the calculation of direct influence and dependence (Walters, 2018). Questionnaires were made to be discussed with experts regarding the relationship between direct and indirect effects of each variable. The scale from MICMAC is used to fill in the relationship matrix between variables through a cross impact matrix (Joshi and Pal, 2015). To find out what variables have an important influence as a factor causing the occurrence of a flood disaster. Based on the results of questionnaires from 7 resource persons from government agencies (BBWS, BNPB, DKI Jakarta Provincial Water Resources Service), universities and experts in the field of disaster control and management, including flood disasters. Based on the opinions of experts, a Likert scale was made to determine or measure qualitative data, to find out a person's opinion, perception or attitude towards the phenomena that occur, so the likert scale is obtained, that is: 0: no influence; 1: very weak influence; 2: weak influence; 3: moderate influence; 4: strong influence.

Table 2 The Likert scale from the opinion of expert sources

	Variable										
	Rainfall	Elev-ation	Slope	Land cover	Soil	River dist	Garbage	Population density	Infras	Institu-tional	EWS
Rainfall	0	4	4	4	4	4	4	3	4	2	4
Elevation	0	0	4	4	4	0	3	3	3	1	2
Slope	0	3	0	4	4	0	3	3	3	2	4
Land cover	0	4	4	0	4	0	3	4	4	3	4
Soil	2	4	4	3	0	2	3	2	4	1	2
River Dist	4	4	4	4	2	0	4	4	3	2	4
Garbage	0	3	3	3	2	0	0	4	3	4	4
Population-density	0	3	4	4	3	0	4	0	3	3	4
Infras	0	2	2	2	1	0	2	2	0	1	3
Institutional	2	1	2	4	2	2	0	3	4	0	4
EWS	0	3	3	3	1	0	2	3	3	P	0

Based on the likert scale, it is converted back to the MICMAC scale and the median value is determined based on the quality of the answers from the opinions of expert sources, to get the middle or median value, the P value (potential influence) in MICMAC is converted to 1 which means the influence or relationship is very weak so that further analysis can be carried out to obtain the most influential factors causing flooding, the results from the likert scale can be seen in Table 2.

MDI Matrix Fill

In accordance with the explanation above, there are 11 variables that will be searched for direct or indirect relationships to determine the influencing factors causing flooding, to find out the relationship, the MICMAC scale (Figure 3) is determined from the likert scale (Table 2), from the converted likert scale to the MICMAC scale of 0 to 3 and P (Description: 0= 0: no influence; 1= P: very weak influence; 2= 1: weak influence; 3= 2: moderate influence; 4= 3: strong influence). Based on these results, the Direct Influence (MDI) matrix for MICMAC software can be determined in figure 3.

	1 : Rainfall	2 : Elevation	3 : Slope	4 : Land cover	5 : Soil	6 : River Dist	7 : Garbage	8 : Population	9 : infras	10 : Institute	11 : EWS
1 : Rainfall	0	3	3	3	3	3	3	2	3	1	3
2 : Elevation	0	0	3	3	3	0	2	2	2	P	1
3 : Slope	0	2	0	3	3	0	2	2	2	1	3
4 : Land cover	0	3	3	0	3	0	2	3	3	2	3
5 : Soil	1	3	3	2	0	1	2	1	3	P	1
6 : River Dist	3	3	3	3	1	0	3	3	2	1	3
7 : Garbage	0	2	2	2	1	0	0	3	2	3	3
8 : Population	0	2	3	3	2	0	3	0	2	2	3
9 : infras	0	1	1	1	P	0	1	1	0	P	2
10 : Institute	1	P	1	3	1	1	0	2	3	0	3
11 : EWS	0	2	2	2	P	0	1	2	2	P	0

Figure 3 Matrix of Direct Influence (MDI)

Variable Mapping

From Figure 4 it can be seen that the variables in the MICMAC analysis will be divided into four quadrants/clusters, namely Influence or key Driver Variable, Relay Variable (Intermediate Variable), Dependent variable, and Autonomous variable. Influence Variable or Key Driver in Quadran I, the variables in this quadrant have a large influence on other quadrants but are less likely to be affected by other variables. in the quadrant, Rainfall and distance from the river are variables that have a significant effect without dependence on other variables. Relay Variable (Intermediate Variable) in Quadran II, which is a variable that has a large effect on the problem but at the same time, it also has a high dependence on other variables. These variables include Land cover, slope, population density, river waste, and soil type.

In this quadrant, the variables are interdependent with other variables. This shows that for flood management, it is necessary to involve the overall variables. The dependent variable in Quadran III, which is a variable that depends a lot on other variables but has a small effect, there are three variables in this quadrant, namely, elevation, early warning system or early warning system, and infrastructure. And then the last variable is Autonomous variable, namely institute, this variable does not have much effect or influence other variables, but for institutions that are located in the middle leading to variable 3, this can be interpreted that the institution is the initial lever that affects other variables, so that Decision makers cannot ignore the institutional position here because it will have a major effect on many other variables.

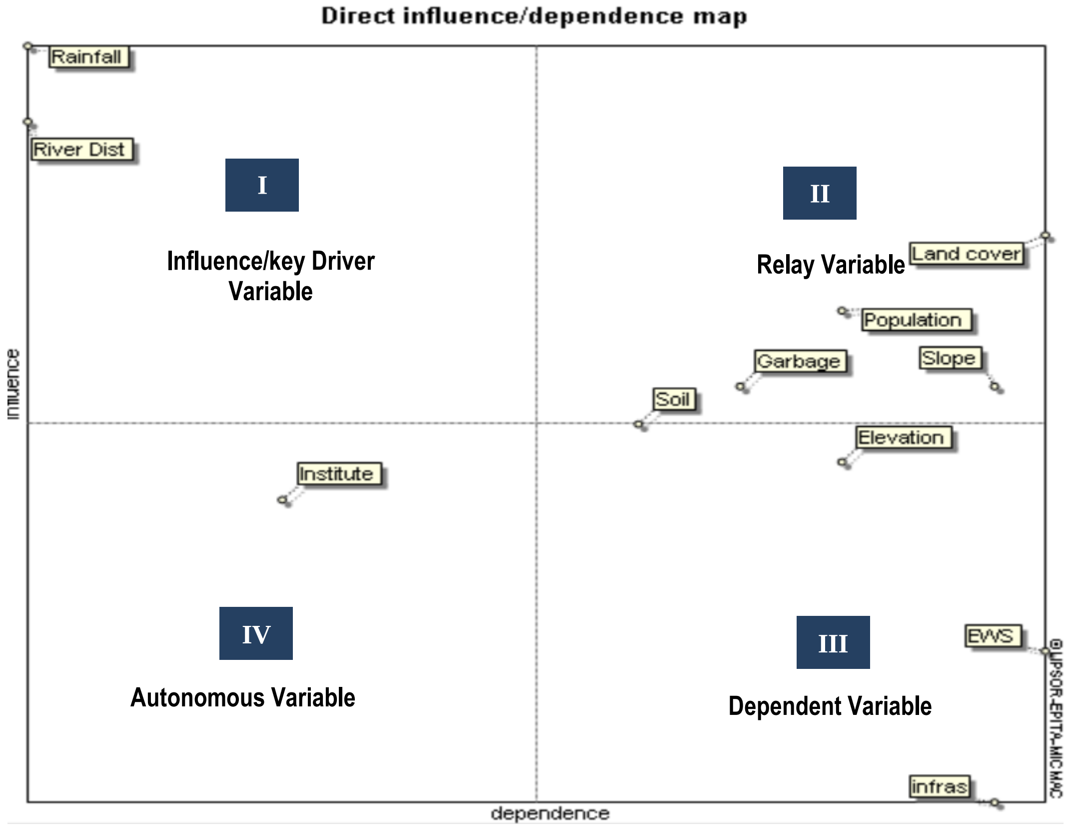


Figure 4 Direct influence factor causing floods

Direct Influence Relationship between Variables

In Figure 5, it can be seen which variable has the most influence and is influenced by other variables, if the arrow comes out the most, it means that the variable is very influential on other variables or affects other variables. If the arrow enters the most, it means that the variable is highly dependent on other variables or influenced by other variables.

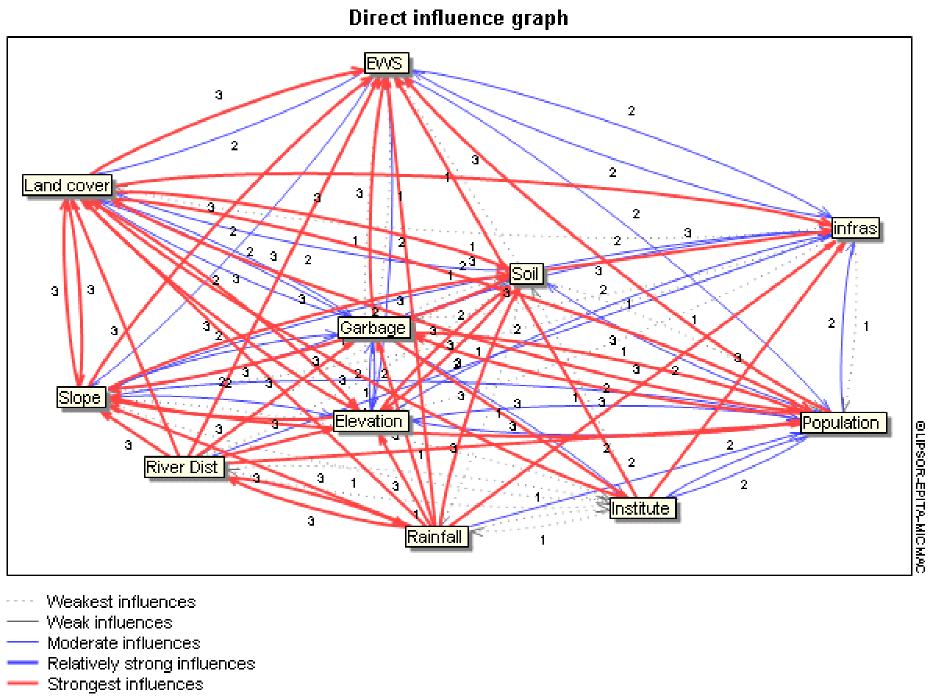


Figure 5 Direct influence between variables 100%

Indirect Influence Relationship between Variables

The indirect influence relationship between variables 100% and 25% can be seen in Figure 6 and 7, respectively. It can be seen that a very strong indirect effect occurs in the variables of rainfall to land cover, infrastructure, slope, and EWS, with the highest scores of 15 311, 15 269 for infrastructure, 11 237 for slope, and 9 579 for EWS. This shows the effect of rainfall on other variables, which indirectly has a major effect on land cover, infrastructure, slope and EWS. While the distance from the river indirectly has a big effect on the EWS with a score of 14 924.

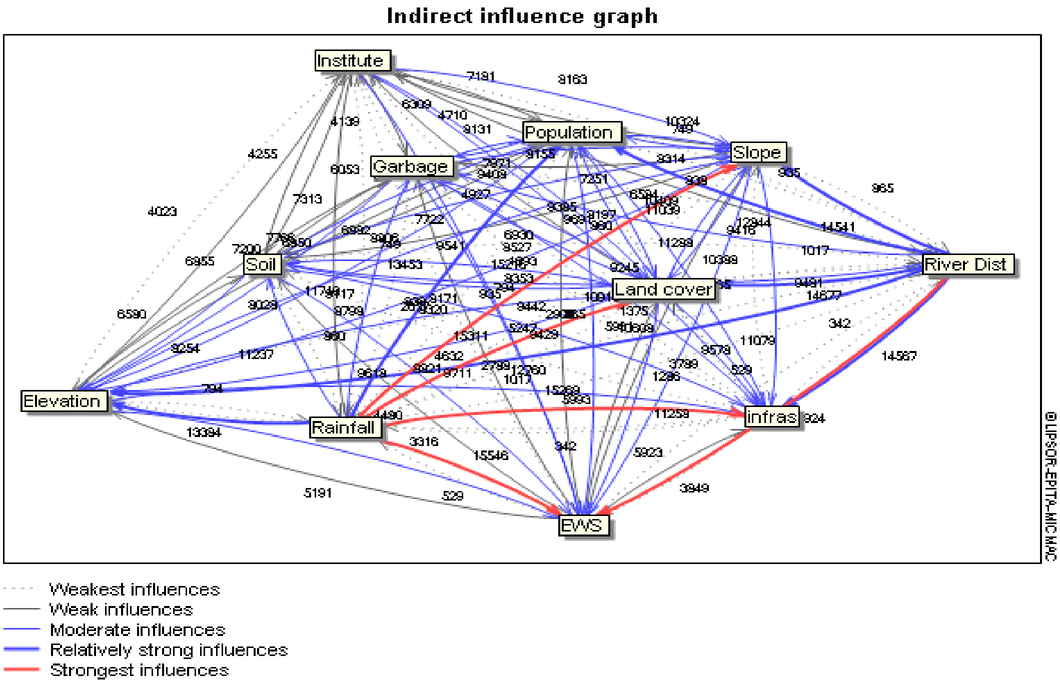


Figure 6 The indirect influence between variables 100%

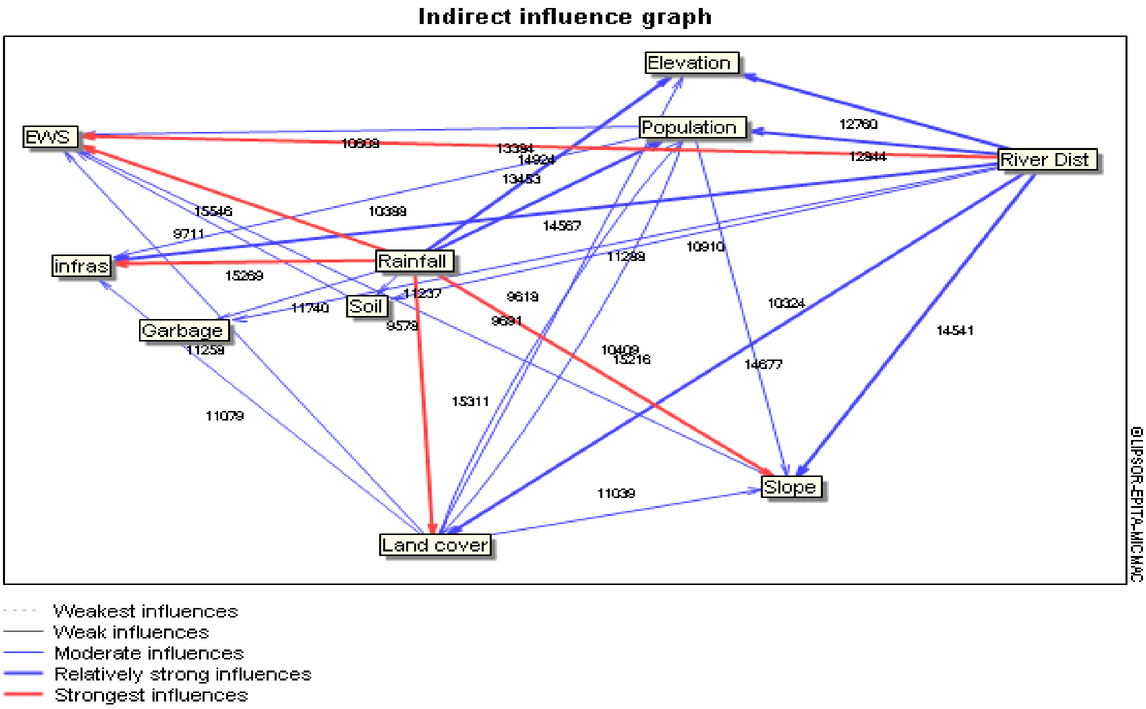


Figure 7 The indirect influence between variables 25%

Ranking of Variables Based on Influence and Dependence

The results of variable rankings based on influence and dependence can be seen in Figures 8 and 9. From the results of the analysis, it can be seen ranking of factors is based on direct influence. With MICMAC software, ranking is carried out based on its effect on other variables, so that it can be seen that the change in variables from MDI to MII (Figure 8), several variables experienced a change in order from MDI to MII after iteration, both increasing and decreasing in order. From Figure 8 it can be seen that the MDI top five variable are rainfall, river distance, land cover, population density and slope slope, from the five variables only the slope changes from number fifth to sixth, so that the number fifth of the MII matrix slope changes to soil type, which increases from the number seventh of the MDI matrix, this means that in the long term soil type will have a greater influence than other variables related to flooding, with waste from sixth in MDI moves to seventh in MII, this means that waste does not have much effect in the long term, because in its application the government manages waste in rivers by installing trash racks or cleaning river garbage with heavy equipment on a regular basis, besides that, many communities are also aware of the impact of garbage in rivers on the environment, especially the effect on flooding, so they carry out river clean activities which are a combination of people care about rivers, the community and the government (Putranto, 2021).

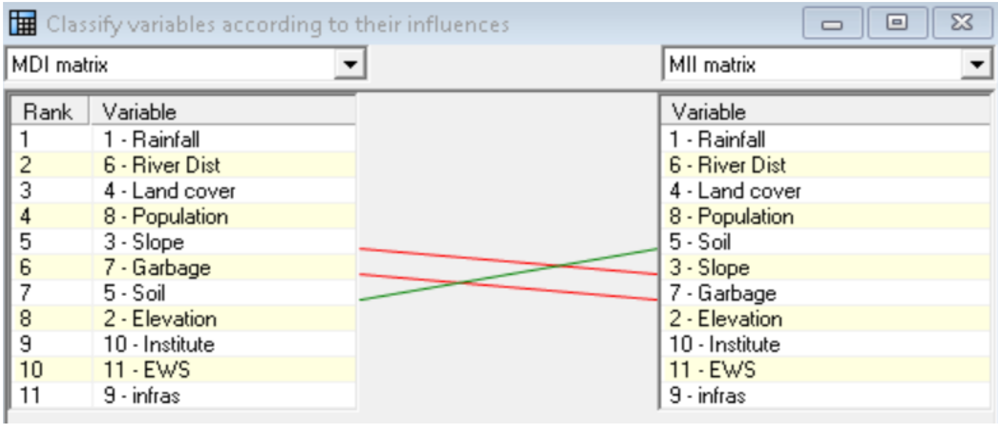
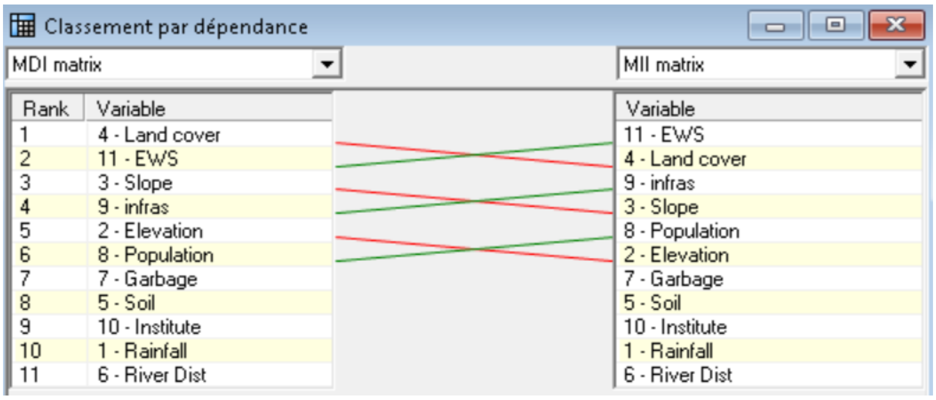


Figure 8 Changes in the ranking variable from MDI to MII based on influence

Based on the level of dependence, the variables can be changed in the ranking (Figure 9). From Figure 9 it is known that the five variables with the highest order based on dependence are land cover, EWS, Slope, Infrastructure, and Elevation. Of the top five, there are three variables that experienced a not very significant decrease, which dropped one rank from MDI to MII, namely land cover, slope, and elevation variables. While the variables that experienced an increase based on the level of dependence were EWS, Infrastructure, and population density, each of which increased by one rank, meaning that the three variables in the long term had a higher dependence which was influenced by more other variables. Based on the results of the study that land use and land cover changes have an important effect on intensifying the flooding process (Dewan dan Yamaguchi 2008) (Thanvisitthpon, 2019) and have an effect on the runoff coefficient, which affects the flood flow discharge (Ariyani *et al.*, 2020).

Changes in the position of variables on the influence-dependence map from MDI to MII can also be known through the displacement map (Figure 10). This map shows which variables have increased, decreased or remained constant in the long term. In Figure 10 it can be seen that most of the changes in variable displacement only occur in the quadrant, except for river waste that moves from quadrant II relay variable to quadrant III dependent variable, with institutions moving from quadrant IV (autonomous variable) to quadrant III (dependent variable).



Rank	Variable (MDI matrix)	Variable (MII matrix)
1	4 - Land cover	11 - EWS
2	11 - EWS	4 - Land cover
3	3 - Slope	9 - infras
4	9 - infras	3 - Slope
5	2 - Elevation	8 - Population
6	8 - Population	2 - Elevation
7	7 - Garbage	7 - Garbage
8	5 - Soil	5 - Soil
9	10 - Institute	10 - Institute
10	1 - Rainfall	1 - Rainfall
11	6 - River Dist	6 - River Dist

Figure 9 Changes in the ranking variable from MDI to MII Based on dependency

Displacement Map

Influence map with indirect displacement (generated in LIPSOR-EPITA MICMAC) (Figure 10), in this influence diagram, the small shaded points represent the influence and relative dependence of each factor based on its direct interaction, whereas displacement is based on indirect interaction represented by lines extending from the shaded points.

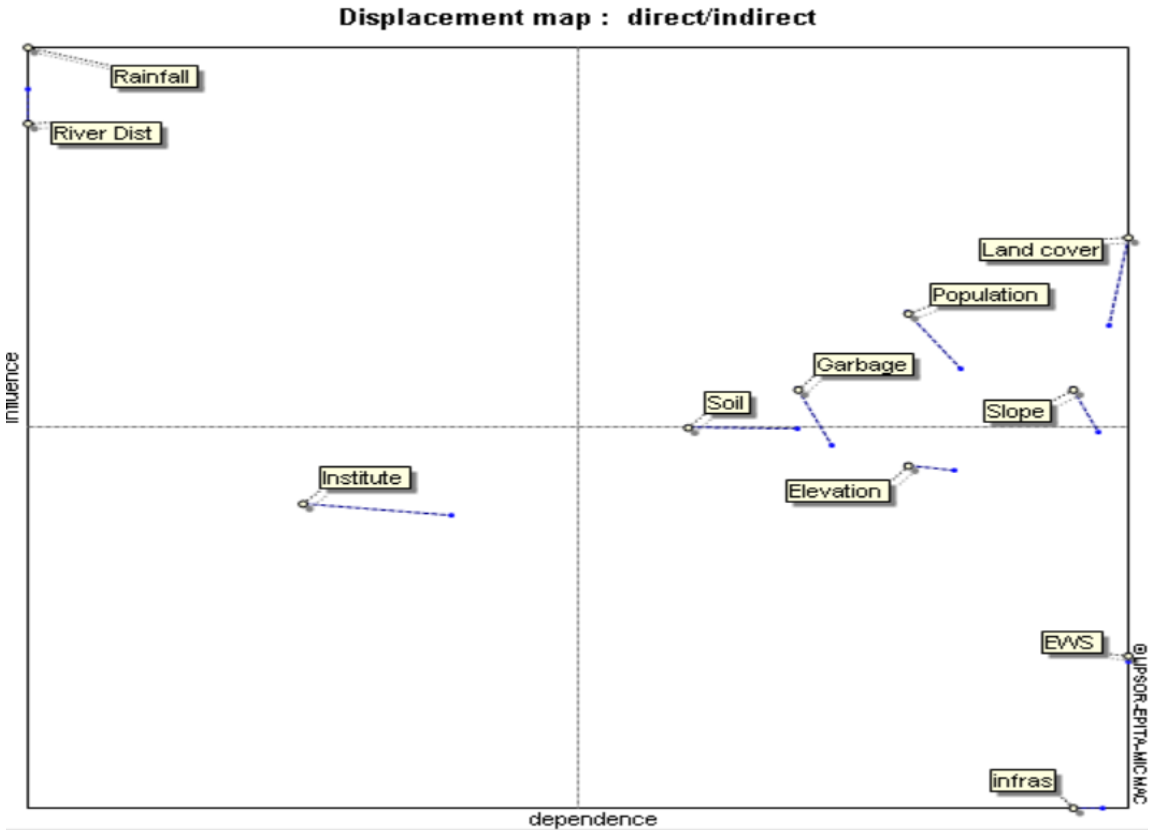


Figure 10 Displacement map by influence direct and indirect

Based on Figure 10, it can be seen that the relative shift of each factor can be interpreted as an indication of how each factor behaves in the wider system. In other words, its effect can increase or decrease depending on how it interacts with other factors. Institutions, land cover population density, garbage in rivers, and soil types shifted the most in this analysis or had the largest displacement. All of these factors will have a greater impact on the system.

CONCLUSION

Flood disasters, especially in developing countries, occur very often, especially in Indonesia, which only has two seasons, namely the dry and rainy seasons, because many factors cause floods such as natural factors from rainfall and human or anthropogenic factors such as changes in land cover, poor infrastructure. Inadequate, including poor drainage systems, and when developing strategies and scenarios in flood disaster reduction, often the available methods fail to reveal the essence of the complex flood control system. Therefore, the main purpose of this study is to overcome this problem by finding the most influential factors that cause flood disasters with the MICMAC method to determine various classifications of variables. By taking the Ciliwung Watershed as the study location to show the variables that cause flooding. The key variables or influence variables on flood hazard are in quadrant I, namely rainfall and distance from the river.

From the results can see various types of variables and their effects on flooding. From the actual direct influence variable to the potential dependence of the indirect variable, they show the same influence or dependence on each other. In addition, the MICMAC method makes it possible to make priorities for each variable that helps policy and decision making to be able to identify the most influential variable according to its dependence and influence on other variables in the second quadrant, which has a high dependence on other variables are land cover, population density, slope, soil type and garbage in the river, and then in the third quadrant is a variable that has a small effect but depends a lot on other variables, namely elevation, EWS kand infrastructure, and in the fourth quadrant which does not have much effect or influence other variables is institutional.

The results of the Ciliwung Watershed based on the MICMAC, it can be explained that the key variables causing floodings are rainfall and the distance from the river based on the direct influence matrix, with the first number that affects the most is rainfall, which means that rainfall directly affects the occurrence of flood disasters, with the distance from the river being in second place, which means the distance from settlements to the river has an effect on the impact of the flood disaster, so that what the government does to reduce the impact is by making regulations on river boundaries (Indonesian Government Regulation, 2011) is appropriate, but in this case, there is a lack of supervision over the implementation of the regulation, so it doesn't run optimally. Other direct influence factors that cause flood disasters that have a major impact on the problem but at the same time also have a high dependence on other variables are trash in rivers, population density, land cover, and slopes called relay variables, while the type of soil is on the relay variable and dependent variable, this means that the type of soil here has a strong dependence on other variables, but the effect is not too large on other variables. All types of variables, both hazard, vulnerability, and capacity factors, will have a large and interrelated effect, this can be seen by the many variables that are in quadrant 2, of course, the existence of variables in this quadrant must receive special attention and handling, because their attachment to other variables is quite large, while for quadrant 3, namely Elevation/topography, EWS, and Infrastructure, it has a dependence on other variables, which affect flood disaster management.

Any improvement in understanding the key variables of a system will lead to the formation of better scenarios and strategies for the development of the system. Although the MICMAC method can describe the complexity of the relationship between variables in detail, this method needs to be developed further so that it can better reflect the interdependence between variables, including economic, social, environmental, religious education, and others that can cause flood disasters, which are more diverse and complex in developing countries, in this case, conducting a comparative study of the effectiveness of various methods such as MICMAC in combination with AHP or ISM to show more complex results by comparing several methods.

ACKNOWLEDGMENT

Thanks to the Research Institute of the Faculty of Engineering, University of Pancasila, for the funds provided.

REFERENCES

[BNPB] National Disaster Management Agency. 2022. *Kejadian Bencana Tahun 2021* [Internet]. [accessed 2022 Jan 9]. Available at: https://bnpb.go.id/infografis/kejadian-bencana-tahun-2021.

Ahmed MT, Saleh M. 2009. El maghara scenario a search for sustainability and equity an egyptian case study. *J Futur Study*. 14(2): 55-90.

Ajim S, Parvin F, Bao Q, Vojtek M, Vojteková J, Costache R, Thi N, Linh T, Quan H, Ahmad A. 2020. GIS-based comparative assessment of fl ood susceptibility mapping using hybrid multi-criteria decision-making approach, naïve Bayes tree, bivariate statistics and logistic regression : A case of Top l' a basin, Slovakia. *Ecol Indic.* 117(2): 1-23. doi: 10.1016/j.ecolind.2020.106620.

Ambrosio-albala M, Delgado M. 2008. Understanding rural areas dynamics from a complex perspective an application of prospective structural analysis. *12th EAAE Congr 'People, Food Environ Glob Trends Eur Strateg*; 2008 Aug 26-29; Gent, Belgia. Gent (BE): EAAE.

Arifasihati Y, Kaswanto. 2016. Analysis of land use and cover changes in Ciliwung and Cisadane Watershed in three decades. *Procedia Environ Sci.* 33: 465-469. doi: 10.1016/j.proenv.2016.03.098.

Ariyani D, Aprilia V, Juniati AT, Dewi A, Kurnia F. 2020. Curve number method to determine the runoff height in the upper Cimanuk Watershed. *IOP Conf Ser Mater Sci Eng.* 852(1): 1-6. doi: 10.1088/1757-899X/852/1/012020.

Bashir H, Ojiako U. 2020. An integrated ISM-MICMAC approach for modelling and analysing dependencies among engineering parameters in the early design phase. *J Eng Des.* 31(8-9): 461-483. doi: 10.1080/09544828.2020.1817347.

Benjumea-arias M, Castañeda L, Valencia-Arias A. 2020. Structural analysis of strategic variables through MICMAC use case study Leonel Castañeda Alejandro Valencia-Arias. *Mediterr J Soc Sci.* 7(4): 11-19. doi: 10.5901/mjss.2016.v7n4p.

Bian G, Du J, Song M, Zhang Xueliang, Zhang Xingqi, Li R, Wu S, Duan Z, Xu C. 2020. Detection and attribution of flood responses to precipitation change and urbanization: A case study in Qinhuai River Basin, Southeast China. *Hydrol Res.* 51(2): 1-15. doi: 10.2166/nh.2020.063.

Christian R, Hutauruk H, Alfiandy S, Nainggolan HA. 2020. GIS-based flood susceptibility mapping using Overlay Method in Central GIS-based flood susceptibility mapping in Central Sulawesi. *Indones J Spat Reg Anal.* 34: 136-145. doi: 10.23917/forgeo.v34i2.10667.

Delgado-serrano MM, Vanwildemeersch P, London S, Ortiz-guerrero CE, Semerena RE, Rojas M. 2016. Adapting prospective structural analysis to strengthen sustainable management and capacity building in community-based natural resource management contexts. *Ecol Soc.* 2(2): 1-14. doi: 10.5751/ES-08505-210236.

Dewan A, Yamaguchi Y. 2008. Effect of land cover changes on flooding: Example from Greater Dhaka of Bangladesh. *Int J Geoinformatics*. 4: 11-20.

Putranto ED. 2021. *Aksi Pecinta Alam Bersihkan Sungai Ciliwung* [Internet]. [accessed 2022 Feb 2]. Available at: Republika.co.id.

Fauzi A. 2019. *Teknik Analisa Berkelanjutan*. Fajariyanto, editor. Jakarta (ID): Gramedia Pustaka Utama.

Indonesian Government Regulation. 2011. Peraturan Pemerintah Republik Indonesia Nomor 38 Tahun 2011 Tentang Sungai. Jakarta (ID): Indonesian State Secretariat.

Isa M, Fauzi A, Susilowati I, Muhammadiyah U, Tengah J, Economics E, Tengah J. 2019. Flood risk reduction in the northern coast of Central Java Province, Indonesia An application of stakeholder's analysis. *J Disaster Risk study*. 11(1): 1-9.

Joshi A, Pal DK. 2015. Likert scale: Explored and explained. *Br J Appl Sci Technol.* 7(4): 396-403. doi: 10.9734/BJAST/2015/14975.

Nugroho SP. 2008. Analisis curah hujan penyebab banjir besar di Jakarta. *JAI*. 4(1): 50-55.

Panahi A, Alijani B, Mohammadi H. 2010. The effect of the land use/cover changes on the floods of the Madarsu Basin of Northeastern Iran. *J Water Resour Prot.* 2010(2): 373-379. doi: 10.4236/jwarp.2010.24043.

Paulus CA, Fauzi A. 2017. Factors affecting sustainability of alternatives livelihood in coastal community of Nembrala, East Nusa Tenggara an Application of Micmac Method. *J Ekon Pembang.* 18(2): 175-182. doi: 10.23917/jep.v18i2.4397.

Perera D, Seidou O, Agnihotri J, Wahid A, Rasmy M. 2019. *Flood Early Warning Systems: A Review Of Benefits, Challenges And Prospects*. Canada (US): United Nation University.

Sholihah Q, Kuncoro W, Wahyuni S, Suwandi SP, Feditasari ED. 2020. The analysis of the causes of flood disasters and their impacts in the perspective of environmental law. *IOP Conf Ser Earth Environ Sci.* 437: 1-7. doi: 10.1088/1755-1315/437/1/012056.

Shi L. 2020. Beyond flood risk reduction: How can green infrastructure advance both social justice and regional impact?. *Socio-Ecological Pract Res.* 2(4): 311-320. doi: 10.1007/s42532-020-00065-0.

Sunarharum TM. 2021. Membangun ketangguhan dan adaptasi transformatif: Kasus pengurangan risiko bencana banjir di Jakarta. *Reka Ruang*. 3(2): 71-80.

Teimouri R, Hodjati H. 2017. Structural analysis of affecting factors for future development of green spaces in Tabriz City. *Asian Soc Sci.* 13(3): 185-197. doi: 10.5539/ass.v13n3p185.

Thanvisitthpon N. 2019. Impact of land use transformation and anti-flood infrastructure on flooding in world heritage site and peri-urban area: A case study of Thailand's Ayutthaya province. *J Environ Manage.* 247: 518-524. doi: https://doi.org/10.1016/j.jenvman.2019.06.094.

Titley HA, Cloke HL, Harrigan S, Pappenberger, Prudhomme C, Robbins C, Stephens EM, Zsótér. 2021. Key factors influencing the severity of fluvial flood hazard from tropical cyclones. *J Hydrometeorol.* 22: 1801-1817. doi: 10.1175/JHM-D-20-0250.1.

Veltmeyer J, Sahin O. 2014. Modelling climate change adaptation using cross-impact analysis an approach for integrating qualitative and quantitative data Modelling climate change adaptation using cross-impact analysis: An approach for integrating qualitative and quantitative data. *Int Environ Model Softw Soc*. 4: 1945-1952.

Walters J. 2018. A systems analysis of factors influencing household Solar PV adoption in Santiago, Chile. *Sustainability*. 10: 1-17.doi: 10.3390/su10041257.

Yilmaz AG, Hossain I, Perera BJC. 2014. Effect of climate change and variability on extreme rainfall intensity–frequency–duration relationships: A case study of Melbourne. *Hydrol Earth Syst Sci*. 18: 4065-4076. doi: 10.5194/hess-18-4065-2014.