International Journal of GEOMATE, Dec., 2019 Vol.17, Issue 64, pp. 230- 237
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.64.64420
Geotechnique, Construction Materials and Environment

MANAGEMENT OF FLOOD HAZARD AREAS IN PASAMAN RIVER BASIN OF WEST PASAMAN REGENCY WEST SUMATRA PROVINCE

*Indang Dewata[1] and Iswandi Umar[2]

[1]Program Pascasarjana, Padang State University, Padang; [2]Departement Geography, Faculty of Social Sciences, Padang State University, Padang; Indonesia

*Corresponding Author, Received: 15 July 2019, Revised: 23 Aug. 2019, Accepted: 26 Sept. 2019

ABSTRACT: Floods have caused many losses to human life. Indonesia has around 30 percent of its area is flood hazard. If the disaster hazard areas occupied by the low capacity of society, this condition will cause a high risk of disaster. Arranging the river basin management policy is one of the flood mitigation efforts. This study aims to determine the arrangement of river basin management policy in Pasaman. Geographic Information System (GIS) approach is used to determine the flood hazard areas in the Pasaman river basin. Indicators in determining flood hazard areas are slope, rainfall, land type, land use, and landform. In arranging the policy directives of the Pasaman river basin management, this research used Interpretative Structural Modeling (ISM) approach. In setting the directives policy, twenty experts from relevant stakeholders work together. The results show that around 25 percent of river basin areas in Pasaman is a high flood hazard risk areas. The result also set a priority to reduce sedimentation in rivers in the Pasaman river basin management policy.

Keywords: Flood, River basin, Policy, Management, Flood hazard areas.

1. INTRODUCTION

Floods are the most frequent disasters happen in many regions in Indonesia. About 30 percent of natural disasters is flooding. Besides, Ganiyu *et al*. estimated that in 2030 about half of the life of the planet Earth will feel the impact of floods. Therefore, the necessary solutions for future mitigation [1]. Zhou *et al.* added that due to global climate change, the flood damages continue to increase in the future [2]-[3]. Furthermore, Yu *et al.* [3] stated that the increase in disasters is closely related to the climate change phenomenon. Increasing of the earth's temperature drives the acceleration of the hydrological cycle, so that rainfall lasts longer and is evenly distributed.

Flood disasters can occur due to three main factors, namely: a) meteorological factors; b) river basin characteristics; and c) human behavior. High rainfall intensity and duration distributed along the river basin can cause flooding. Besides, areas with relatively flat topography and poor water drainage may also lead to flooding.

Efforts to reduce losses caused by floods are arranging flood mitigations. Dewan *et al.* [4] stated that the weakness of developing countries in determining flood hazards is that there is not enough information available on indicators of determining vulnerability levels; this will affect a fault on the zoning hazards area. Furthermore, Floris *et al.* stated that floods in developing countries are mostly caused by the inconsistencies of law enforcement regarding spatial violations [1]-[4]-[5].

The Pasaman river basin encounters floods every year and causes loss to many people. The high intensity of rainfall, deforestation, and the lack of law enforcement against forest destruction are considered as the main factors causing the flood. Flood mitigation efforts in the Pasaman river basin need to have a map of flood hazard areas and a guide for land-use policies. Therefore, this study aims to determine the arrangement of river basin management policy in Pasaman.

2. RESEARCH METHODS

2.1. Location and Time of Study

The location of the Pasaman River basin is in West Pasaman Regency, West Sumatra Province. Geographically, it is located at 99º40’-100º03’E of latitude and 0º02’S -0º30’N of longitude with an area of 118,874 ha. This research was conducted for six months, specifically in June 2018 until November 2018. Fig. 1 shows the map of the research location.

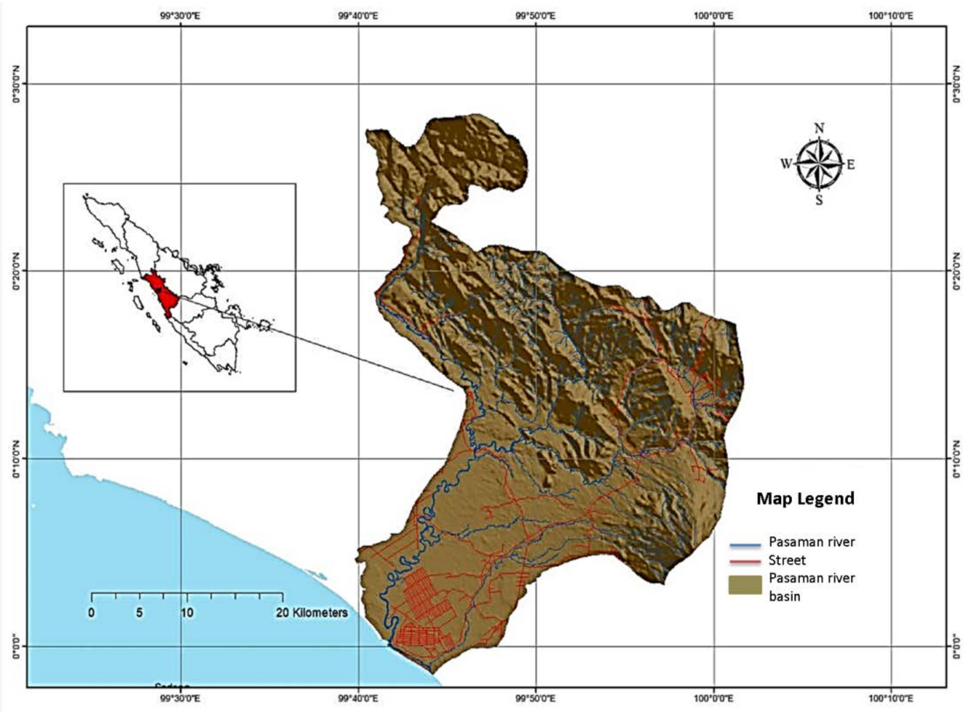

Fig. 1 Map of the research location

2.2. Types of Research Data

Data in the study can be classified into two types, particularly primary data and secondary data. The primary data are taken from observations and interviews. While secondary data are collected from related institutions. Table 1 presents the matrix of research data needs.

Table 1. The matrix of research data needs

No	Types of data	Sources
1	Land slope	*Shuttle Radar Topography Mission (SRTM)* image
2	Land use	landsat oli 8 image
3	Land type	Land type map taken from, Map of Land Type (PPT 1990) with a scale of 1 : 250 000
4	Rainfall intensity	Interpolation of the rainfall data of Sicincin BMKG in 1975-2017
5	Land form	RePProT in 1990

Source : Umar (2018), Umar *et al.* (2019)

2.3. Data Analysis Technique

The determination of flood hazard areas maps in the Pasaman river basin is apprehended from five indicators, namely: slope, rainfall, land type, landform, and land use. Each indicator is classified into several sub-indicators. Table 2 shows the indicators for determining flood hazard areas in the Pasaman river basin.

Determining flood hazard areas was done by fuzzy analysts using the Geographic Information System (GIS). The score on flood hazard indicators are adjusted to values ranging from 0 to 1, and the value of the indicator was analyzed through fuzzy membership. Then, the overlay of the flood hazard area indicator is designed through a fuzzy overlay.

The policy directives for the management of Pasaman river basin area were analyzed using the Interpretative Structural Modeling (ISM) method. The ISM method analyzes data by processing a particular group assessment to make a certain structural model. This model is composed to depict complex matters in a system through carefully designed patterns with graphics and sentences [9]-[10]. The ISM method is considered sufficiently effective to structure complex issues, for it is used to define and clarify issues, assess impacts, and identify relationships among policies.

The basic principle of the ISM method is identifying structures in a system providing beneficial values to design the system effectively in making a better decision. The methodology of the ISM technique is included compiling a hierarchy and classifying its sub-elements [6]-[7]-[9]-[10]-[14]. In general, the stages of ISM method are as follows:

1) Elaborating each element into several sub-elements.
2) Determining the contextual relationship between the sub-elements of each element showing paired comparisons whether the contextual relationship exists or not based on experts' opinion.

3) Arranging the Structural Self Interaction Matrix (SSIM) using the symbols V, A, X, and O.
4) Making the Reachability Matrix (RM) table by replacing the symbols V, A, X and O with numbers 1 or 0.
5) Leveling the sub-element in each element vertically or horizontally.
6) Arranging the Driver Power Dependence (DPD) matrix for each sub-element. The classification of elements is divided into four quadrants, namely::
   a. Quadrant I: Not related (Autonomous) consists of sub-elements that have a driver power value (DP) ≤ 0.5 X and dependence value (D) ≤ 0.5 X. Where X is the number of sub-elements in each element. Sub-elements in quadrant I am generally not related / small to the system.
   b. Quadrant II: Not free (Dependent) consists of sub-elements that have a driver power value (DP) ≤ 0.5 X and dependence value (D) ≥ 0.5 X. Where X is the number of sub-elements in each element. Sub-elements that are in quadrant II are sub-elements that depend on elements in quadrant III.
   c. Quadrant III: Linkage consists of sub-elements that have a driver power value (DP) ≥ 0.5 X and dependence value (D) ≥ 0.5 X. Where X is the number of sub-elements in each element. Sub-elements that are included in quadrant III need to be studied carefully because each action on one sub-element will affect other sub-elements in quadrant II and IV.
   d. Quadrant IV: Activator (Independent) consists of sub-elements that have a driver power value (DP) ≥ 0.5 X and dependence value (D) ≤ 0.5 X. Where X is the number of sub-elements in each element.

Table 2. Flood Hazard Indicator

Indicator/value	Sub Indicator	Value	Score
Slope/10	Very gentle spoles (0-8 percent)	1	10
	Strong slopes (9-16 percent)	2	20
	Very strong slopes (17-26 percent)	3	30
	steep slopes (27-45 percent)	4	40
	Very steep slopes (>45 percent)	5	50
Rainfall/7	<2000 mm/year	1	7
	2000-3000 mm/year	2	14
	3000-4000 mm/year	3	21
	4000-5000 mm/year	4	28
	>5000 mm/year	5	35
Land type/5	Alluvial	4	20
	Andosol	3	15
	Glei humus	5	25
	Kambisol	3	15
	Latosol	2	10
	Regosol	4	20
Land use/5	Forest	1	5
	Plantation	2	10
	Mixed gardens	3	15
	Rice fields	3	15
	Human settlement	5	25
	Clearing	4	20
	Bush	2	10
Landform/8	*Oxbow lake*	6	48
	Coastal alluvial plains	5	40
	Alluvial plain	4	32
	Volcanic Alluvial plain	3	24
	Volcanic toe slopes	3	24
	Volcanic foot slopes	3	24
	Volcanic back slopes	2	16
	Volcanic shoulder	1	8
	Rubber hills	1	8

Sources : Umar *et al.* (2017), Umar (2018), Umar dan Dewata (2018), Umar *et al.* (2019)

Experts in determining the policy directives of the Pasaman river basin management are from relevant stakeholders, including Population and Environmental Research Center of Universitas Negeri Padang, Environmental Services of West Sumatra Province. Development Planning Agency at Sub-National Level of West Pasaman District, Environmental impact Control Agency at Sub-National Level of West Pasaman, Public Works Service of Pasaman District, and the society. The number of experts involved in the study was 20 people. These experts work in two stages in the research; determining the flood hazard areas and designing policy directives of the management of the area. Fig. 2 presents the stages of research.

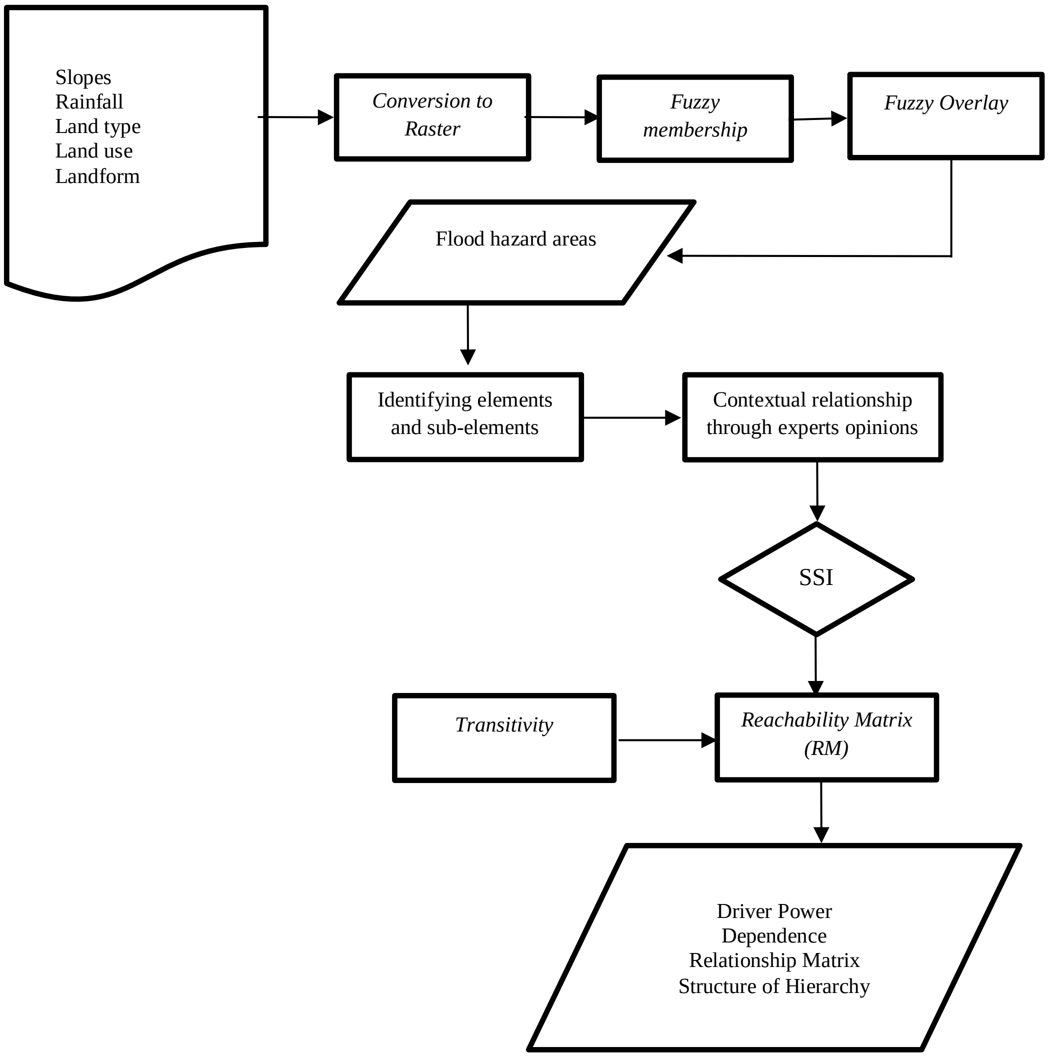

Fig. 2 Stages of the research

3. RESULTS AND DISCUSSION

The Pasaman river basin has the most extensive river basin area in Pasaman Regency. In the region, there are nine watersheds with dendritic patterns. About 30 percent of the region experiences floods every year, due to the areas ' characteristics where almost 50 percent of them are plain. Besides, the land-use of the forest area at the upper watershed is only around 20 percent. Conversion of land use from primary forest to other uses is one of the factors causing floods. In ten years, there have been rapid changes in the land use into plantations in the Pasaman river basin. The land-use conversion caused an increase in river sediment, and the river became shallow. Furthermore, the morphological conditions of the area that are relatively flat in the estuary and large river basin area are the factors causing flood hazards. Fig. 3 presents the morphology and land-use of the Pasaman river basin

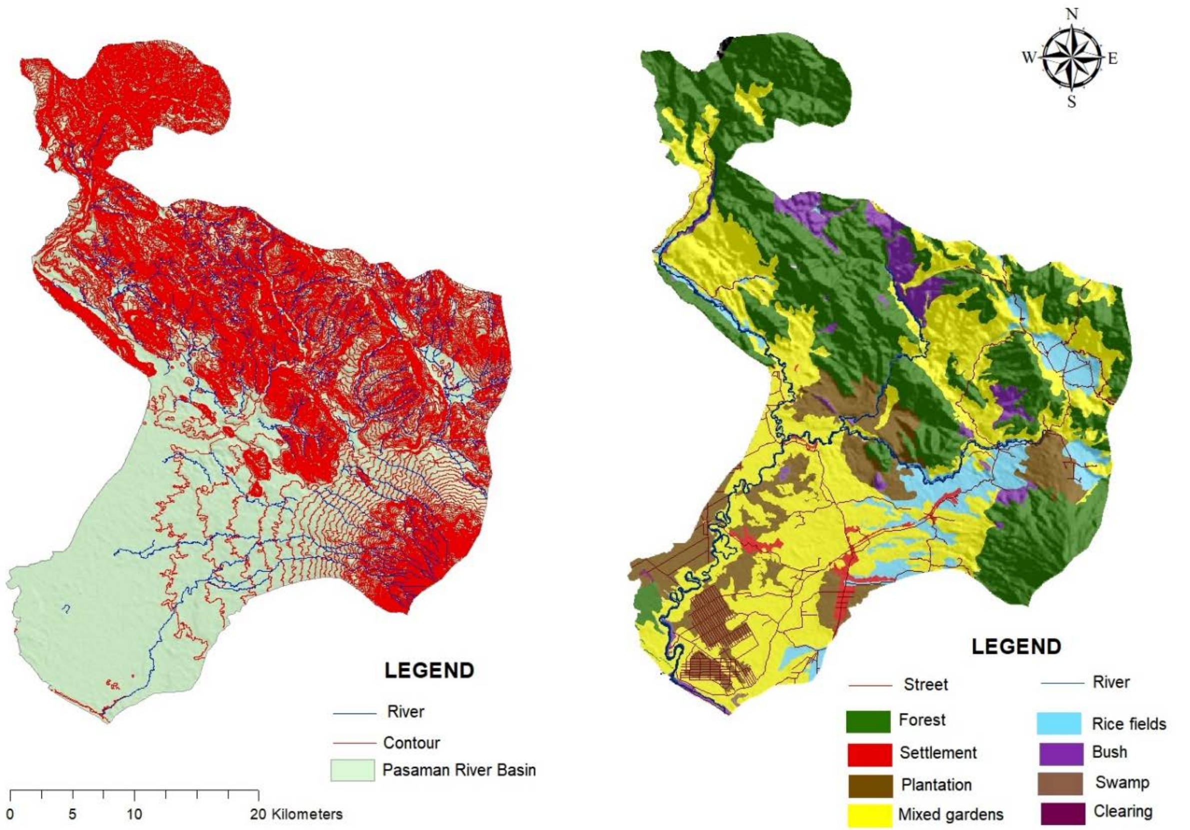

Fig. 3 Morphology and land-use of the Pasaman river basin

Human life cannot be separated from the use of land. Land and soil are important resources for human life. The more the population lived in a region, the more pressure on its land increases and the more conflict of interest exist in land use. According Sadyohutomo revealed that an increase in population encourages an increase in the need for land use [11]-[15]. The area of land that can be utilized to support life is relatively constant and limited. As a result, there will be competition for land use. In the end, there will be conflicts among the users, and it will also cause land degradation. According to Muta'ali , high population growth causes humans to use natural resources regardless of the ability and carrying capacity of the environment. As a result, there will be a decrease in the quality of the environment, and there will be natural disasters [12]-[16].

Fig. 4 is a flood hazard zoning of the Pasaman river basin, the results of the analysis show that around 25 percent is a high flood hazard zone, 30 percent is moderate flood hazard zone, and the remaining 40 percent is a low flood hazard zone. Areas that have high hazard of flood are used for settlements, plantations, rice fields and mixed gardens.

Patterson and Doyle suggested that high population growth encourages humans to move and occupy areas at risk of disaster. This is happening because the land that can be used to meet the needs of human life is limited. Also, the degradation of the economic value of land forces many people to live in disaster-prone areas [13].

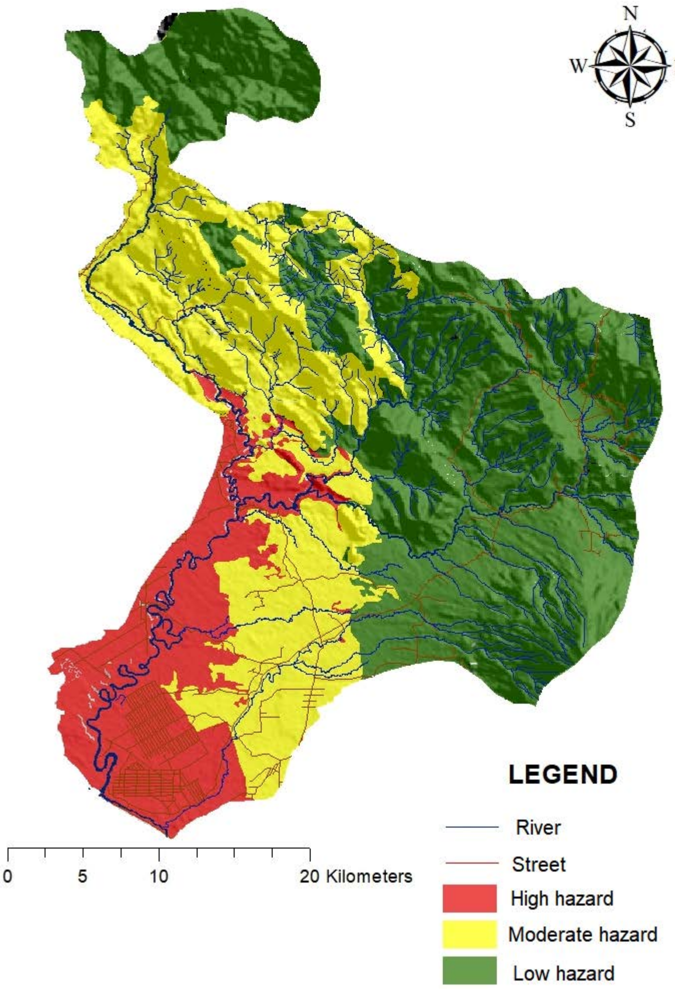

Fig. 4 Flood hazard area of Pasaman river basin

The policy directives of the Pasaman river basin management is carried out by using the ISM approach. Twenty experts were involved in determining the policy directives. They are from related stakeholders, namely: Universitas Negeri Padang, Population and Environmental Research Center of UNP, Environmental Agency of West Pasaman Regency, Development Planning Agency at Sub National Level of West Pasaman District, Environmental impact Control Agency at Sub-National Level of West Pasaman, Public Works Service of Pasaman District, NGOs and the society. The identification of spatial planning problems results serves as the policy directives of the Pasaman river basin management. There are eight elements of the policies;

E1. Conservation and reforestation of the upper part of the river basin
E2. Making dams and water reservoir
E3. Expansion and improvement of drainage systems
E4. Making bio pores and infiltration wells
E5. Regulation of space utilization (30%)
E6. Increasing socialization practices of disaster mitigation
E7. Normalization of the river flow
E8. Dredging of river sediments

The Pasaman river basin management has complex problems and involves many relevant stakeholders. The most appropriate efforts to solve complex problems can be analyzed by the ISM approach [6]-[9]-[10]. The result of the policy directives analysis of the Pasaman river basin management shows that the E8 element that is dredging river sediments categorized into the independent quadrant. Independent elements are those with a high driving power and low or no dependence on other elements. Elements that belong to the independent quadrant are the key elements and have huge influences on others. Moreover, the analysis results also indicated six elements in the linkage quadrant. In this quadrant, the elements have high driving forces and dependence on others. Additionally, there is only one element in the dependent quadrant, E2 (making dams and water reservoir). Dependent quadrant elements are elements that have low driving factors and high dependence on other elements. Fig. 5 and Fig. 6 present graphs of the driver power and dependence correlation in the policy directives of the Pasaman river basin management.

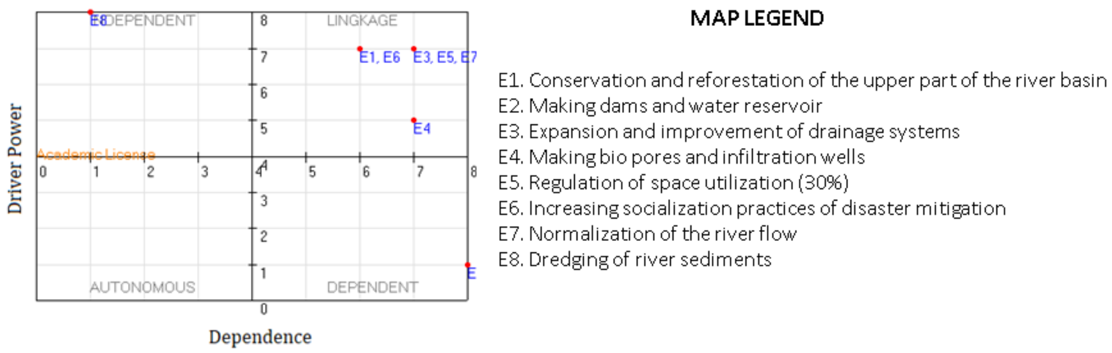

Fig. 5 Graph of the driver power and dependence relationship

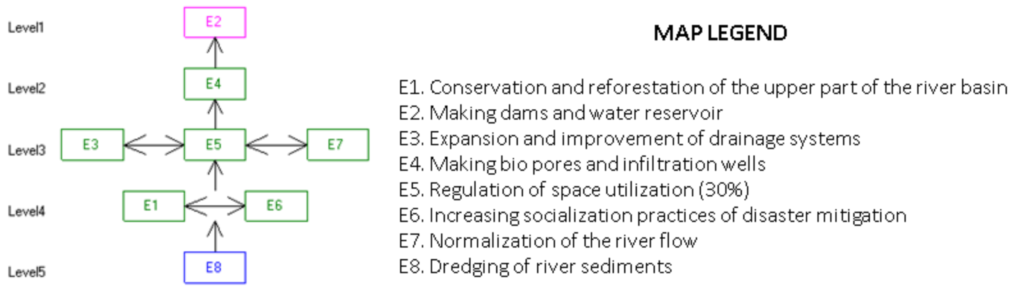

Fig. 6 Structure of policy directives in Pasaman river basin management

4. CONCLUSION

The Pasaman river basin has the characteristics of areas categorized as flood hazard areas. About 25 percent of the area is in high flood hazard areas. The policy directives of the Pasaman river basin management priority are river sediment dredging, conservation, reforestation, and disaster socialization.

5. REFERENCES

1) Ganiyu, M. A., Mohammed, R., and Ismail, A. (2017). Disaster Risk Reduction: Framing Of Flood Disaster In Nigerian Newspapers. *E-Bangi, 12*(1), 151-163.
2) Zhou, Q., Leng, G., and Feng, L. (2017). Predictability Of State-Level Flood Damage In The Conterminous United States: The Role Of Hazard, Exposure And Vulnerability. *Scientific Reports (Nature Publisher Group), 7*, 1-11.
3) Yu, G., Wang, S., Yu, Q., Wu, L., Fan, Y., He, X., and Tian, X. (2014). The regional limit of flood-bearing capability: A theoretical model and approaches. *Water Resources Management, 28*(7), 1921-1936.
4) Dewan, A. M., Islam, M. M., Kumamoto, T., and Nishigaki, M. (2007). Evaluating flood hazard for land-use planning in greater dhaka of bangladesh using remote sensing and GIS techniques. *Water Resources Management*, *21*(9), 1601-1612.
5) Floris Frederik, v. O., Hoekstra, A. Y., and van, d. M. (2005). Flood Management In The Lower Incomati River Basin, Mozambique: Two Alternatives1. *Journal of the American Water Resources Association*, *41*(3), 607-619.
6) Umar, I. (2018). Policy Directives for Sustainable Settlement Development at Flood Hazard Zone in Limapuluh Kota District West Sumatera Province, Indonesia. *Sumatra Journal of Disaster, Geography and Geography Education*, *2*(1), 1-7.

7) Umar, I., Dewata, I., Barlian, E., Anwar, S., and Suasti, Y. (2019). Priority Selection Of Residential Development Areas With Flood Hazard In Limapuluh Kota District, West Sumatra. *International Journal Of Geomate*, *16*(55), 138-144.
8) Umar, I., dan Dewata, I. (2018). Arahan Kebijakan Mitigasi pada Zona Rawan Banjir Kabupaten Limapuluh Kota, Provinsi Sumatera Barat. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan (Journal of Natural Resources and Environmental Management)*, *8*(2), 251-257.
9) Eriyatno, dan Larasati L. (2013). *Ilmu Sistem Meningkatkan Integrasi dan Koordinasi Manajemen.* Surabaya (ID): Guna Widya Pr.
10) Marimin. (2004). *Teknik dan Aplikasi Pengambilan Keputusan Kriteria Majemuk.* Jakarta: Grasindo
11) Sadyohutomo M. (2008). *Manajemen Kota dan Wilayah Realitas dan Tantangan.* Jakarta (ID): Bumi Aksara Pr.
12) Muta'ali L. (2012). *Daya Dukung Lingkungan untuk Perencanaan Pengembangan Wilayah.* Yogyakarta (ID): Badan Penerbit Fakultas Geografi (BPFG) Universitas Gadjah Mada
13) Patterson, L. A., and Doyle, M. W. (2009). Assessing Effectiveness Of National Flood Policy Through Spatiotemporal Monitoring Of Socioeconomic Exposure1. *Journal of the American Water Resources Association*, *45*(1), 237-252.
14) Umar, I. (2016). Mitigasi Bencana Banjir pada Kawasan Permukiman Di Kota Padang Provinsi Sumatera Barat. *Disertasi). Sekolah Pacarjana IPB.* Bagor.
15) Umar, I. Widiatmaka, *Pramudya, B.* dan Barus, B.(2017). Prioritas Pengembangan Kawasan Permukiman Pada Wilayah Rawan Banjir Di Kota Padang, Provinsi Sumatera Barat. *Majalah Ilmiah Globe*, *19*(1), 83-94.
16) Khunwishit, S., Choosuk, C., and Webb, G. (2018). Flood Resilience Building In Thailand: Assessing Progress and The Effect Of Leadership. *International Journal of Disaster Risk Science, 9*(1), 44-54.