The pattern of spatial flood disaster region in DKI Jakarta

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Abstract. The study of disaster flood area was conducted in DKI Jakarta Province, Indonesia. The aim of this research is to study the spatial distribution of potential and actual of flood area. The flood was studied from the geographic point of view using spatial approach, while the study of the location, the distribution, the depth and the duration of flooding was conducted using geomorphologic approach and emphasize on the detailed landform unit as analysis unit. In this study the landforms in DKI Jakarta have been a diversity, as well as spatial and temporal pattern of the actual and potential flood area. Landform at DKI Jakarta has been largely used as built up area for settlement and it facilities, thus affecting the distribution pattern of flooding area. The collection of the physical condition of landform in DKI Jakarta data prone were conducted through interpretation of the topographic map / RBI map and geological map. The flood data were obtained by survey and secondary data from Kimpraswil (Public Work) of DKI Jakarta Province for 3 years (1996, 2002, and 2007). Data of rainfall were obtained from BMKG and land use data were obtained from BPN DKI Jakarta. The analysis of the causal factors and distribution of flooding was made spatially and temporally using geographic information system. This study used survey method with a pragmatic approach. In this study landform as result from the analytical survey was settlement land use as result the synthetic survey. The primary data consist of landform, and the flood characteristic obtained by survey. The samples were using purposive sampling. Landform map was composed by relief, structure and material stone, and process data Landform map was overlay with flood map the flood prone area in DKI Jakarta Province in scale 1:50,000 to show. Descriptive analysis was used the spatial distribute of the flood prone area. The result of the study show that actual of flood prone area in the north, west and east of Jakarta lowland both in beach ridge, coastal alluvial plain, and alluvial plain; while the flood potential area on the slope is found flat and steep at alluvial fan, alluvial plain, beach ridge, and coastal alluvial plain in DKI Jakarta. Based on the result can be concluded that actual flood prone is not distributed on potential flood prone

1. Introduction
Floods as natural disasters that could potentially damage and harm life even human sacrifice [9] states that the flood become a problem when it interferes with the activity of human lives and livelihoods even threaten her safety. Gupta [5] noted the incidence of flooding and its geographical locations such as major flood events in the north and northeast of Australia [16]. Bemelen [3] and Verstappen [14] and [15] wrote about classification of Jakarta landform based on the origin of its formation namely landform from the process of fluvial, fluvial-coastal, and coastal. A characteristic of landform’s origin was identified as landform that was layered by sedimentary rocks of volcanic-fluvial and coastal-
fluvial. The topography of landform was gently sloping to flat with low altitude and even on the coastal alluvial plain landform whose altitude lower than sea level. Aside of this landform, there was another landform in the north side of Jakarta, e.g. beach ridge that was parallel to its coastline. The location of beach ridge landform prevented surface flow derived from central and southern Jakarta during heavy rainfall which headed to northern part of Jakarta Bay. Beach ridge usually had hollow between shelves that could serve as water reservoir, but this area had been built as well. If heavy rains continuously flushed in the basin between shelves, this then would be the Prone area of flood as well. Bappenas [2] noted that built up land use in Jakarta reached 610,752 km$^2$ (61,075.2 hectares) or 93.44% of total area of alluvial landforms in Jakarta. Even, the land use for settlement reached 456,626 km$^2$ (45,662.6 Ha) or 69.86% of total area of built land use which was equivalent to 65.27% from its total area. Agricultural land, parks, and urban forest were the green open space and container land or water park which was left only in amount of 42.94 km$^2$ (4,294.5 hectares) or 6.57%. Besides, damage on agricultural land use and wet land e.g. reservoir/lake/situ which acted as water retention and water reservoir (retarding basin) to settlements and their facilities, were assumed as cause of the increasing and spreading of flood intensity in lowland of Jakarta, both spatially and temporally patterned as prone area of flood. The Prone area of actual and potential floods on the alluvial plain in DKI Jakarta province was always changing, both spatially and temporally (e.g. in 1980 flood = 769,603 Ha., and in 1996 amounted = 2,258.53 Ha). On February 1$^{st}$, 2002 and 2007 there was a flood that had been in large categorized in Jakarta Province [6].

Thus, the landform can be used as a basis for determining flood prone areas of flooding. Flooding that occurs on landform including potential flooding due to natural landform have any vulnerability to flooding. According to the reality on the field was not all landform are in Jakarta or elsewhere are not entirely flooded at the same time. Flooding that occurred at some point it is called the actual flood that a real flood occurred. Prone areas of potential flooding have not necessarily flooded. Based on the background and problems of flooding in Jakarta, the formulation of research problems are as follows. Where is actual and potential flood prone area in DKI Jakarta province?

2. Methods

Methods This study contains study approach, selection of research area, and time, preparation of materials and research materials, determination of research variables, data collection, and data processing and data analysis.

2.1 Study Approach

Study approach in the study of approach spatial flood area in the landform as geomorphological survey approach [14] which survey is divided into three analytic, synthetic survey, and survey pragmatic. This study uses a survey approach pragmatic, because the object studied is associated with flooding. In a survey pragmatic directed to solve problems, in this case is the problem of flooding. The data used in the survey is pragmatic geomorphological survey data analytic and synthetic survey. Analytic survey data is required in relation to the magnitude of floods is morphology, and morphogenesis, whereas the synthetic data for the survey is landform, climate, and land use. Based on a variety of materials in the literature review can be understood that the study of geomorphology in the perspective of geography more emphasis on the similarities and differences of space and time. From the standpoint of fluvial geomorphology in the lower mainland of Jakarta is interesting to study the flooding distributed spatially and temporally. Distribution of flood prone area can be approximated by a unit of flood landform. Pragmatic geomorphological approach, can be used to understand the characteristics of flooding from rivers and fluvial activity fluvio-marine, and can provide answers to problems where the original landform unit as flood prone area flooding. Low land in Jakarta has the magnitude and distribution of rainfall variability. Variations in local rainfall have high rainfall distribution both intensity and thickness. Rainfall in February is the maximum rain that falls on the landform and diverse land use. There are differences in diversity and intensity of heavy rainfall in the north to the south nor the west and east. This difference is due to the location and height landform. When heavy rain with high intensity falls to a variety of landform due to
the hardening of water-proof buildings and facilities house the rain water runoff into water that flooded / flooding in the lower mainland Jakarta different. Genesis there is diversity in lowland landform in Jakarta such as fluvial landform (alluvial fan and alluvial plain), fluvial coastal (beach ridge), and fluvial-marine (coastal alluvial plain). Differences due to differences in topography unit landform (slope and altitude), geology (rocks), and geomorphic processes in the lower mainland Jakarta. In the northern part of Jakarta landmass is dominated by alluvial plain of coastal landform. In addition, on the coast of landform formed beach ridge extending parallel to the coast which blocks the flow of water into the Bay of Jakarta. The origin of fluvial landform, fluvial -marine, and coastal as a potential Prone areas in the flood plain of Jakarta (Figure 1).

![Flow chart of theoretical Framework](image-url)

**Figure 1.** Flow chart of theoretical Framework
2.2 Selection of Research Area and Time

Research areas studied is in the mainland DKI Jakarta 65,493 hectares. The administration areas of study consists of five areas of the city administration, 42 districts, and 261 sub districts. Assumptions of the real (empirical) used in selecting areas that flooded sub districts are as follows: 1) flood due to high daily rainfall. 2) frequently flooded area of 261 sub districts in 107 sub districts. 3) there are differences and similarities in the characteristics of the floodplain areas subject to flooding. 4) population (density and distribution) is relatively large. 5) changing in agricultural land use and wetlands that serve as a rain water to settlement areas.

Flood events discussed in this study is limited to the major flooding that occurred in February of 1996, 2002 and 2007. By reason of the spatial distribution of flood events is the most extensive and diverse and also shows the temporal aspect.

2.3 Materials and Research Equipments

Materials research includes all data related directly and indirectly with the study landform, rainfall, land use, population, and the floods in DKI Jakarta. Research tools used include geological surveying equipment such as geological compass, GPS, helling, altimeter, current meter, flood depth ruler, digital cameras, and motorcycles. Research tools that come from government agencies. measuring equipment in the form of rain is rain gauge instrument manual for daily rainfall data from the agency BMKG, equipment for river water discharge data, and high river water from the Irrigation Department of the Provincial Government of DKI Jakarta.

2.4 Research Variables

1) Variable of climate parameters analyzed were annual rainfall (mm), ten days rainfall (mm), daily rainfall (mm), rainfall duration (hours), and distribution of rainfall (stations). 2) Variable of landform parameters analyzed were relief (altitude and slope), b. material, and c. geomorphic processes. 3) Variable of floods analyzed were flood sites (sub districts), flood area (hectares), depth of flooding (cm), and d. long flood (hour). 4) Variable of land use analyzed were agricultural land area (hectares), wetland area (ha), and settlement land area (hectares).

2.5 Data Collection

Primary data collection was done at the time of field survey in DKI Jakarta are as follows. 1) survey of flood location with a visit to the field. 2) survey flood depth is noticed of marks on the walls of homes flooded as water limits the depth flood. 3) survey of the flood area is obtained from measurements in the sub district flooded by using GPS devices, and Kementerian PU. 4) the survey asked when the old flood flooding and how long homeowners flood events to residents who experienced flooding in their respective units of landform.

Flooding the sample locations in a 37 sub districts was conducted purposively in land-use settlement. This sample is to answer the problem to the correlation flood (area and depth) by land settlement area (Figure 2).
Figure 2. Map Distribution of Sampling Flood location in DKI Jakarta province
3. Research Result and Discussion

3.1 Rainfall
The results of the analysis of rainfall within 12 months (January to December) in 1996, 2002 and 2007 in Jakarta has a thickness variation and the rain are very diverse in their respective stations owned by BMKG Jakarta [1]. There are 8 months rainfall >100 mm, while the 4 months rainfall <100 mm / month. The highest monthly rainfall in January and February respectively more than 300 mm, while the other six months average of 150 mm / month. The graph of rainfall and Map Isohyet on February in Jakarta region in 1996, 2002 and 2007 are presented in Figure 3, and 4.

![Figure 3. Bar chart rainfall in DKI Jakarta on February](image)

![Figure 4. Map Isohyet on February in Jakarta region in 1996, 2002 and 2007](image)
3.2 Distribution of Spatial Potential and Actual in Prone Area

Potential flood prone area in DKI Jakarta land is described as follows (Figure 5). 1) Very high potential flood is located in northern DKI Jakarta. 2) High potential flood is located in central and southern DKI Jakarta. 3) Rather high potential flood is located in eastern DKI Jakarta. 4) Low potential flood is located in the eastern part to south DKI Jakarta. 5) Very low potential flood in DKI Jakarta is located in the southeast on the steep slopes.

Figure 4. Map of Isohyet on February in DKI Jakarta

Figure 5. Map of Potential flood prone area in DKI Jakarta
The actual Prone area flooding in Jakarta in February 1996 accured in 181 sub districts (69.4%). Actual flood prone area on February 2002 has in common with the floods in February 1996. There is a good addition of flooded areas in Jakarta, West Jakarta, Central Jakarta, North Jakarta and South Jakarta. Actual flood prone area in DKI Jakarta province on February 2007 has in common with the floods in February 1996 and 2002. There are additional areas of flooding in East Jakarta, West Jakarta, North Jakarta and South Jakarta except Central Jakarta, and North Jakarta (Figure 6).

Figure 6. Map Actual flood prone area in DKI Jakarta province

3.3 Comparative Potential and Actual in Flood Prone Area

Geomorphological approaches that have been used by Thornbury [11], and Spark [10] and Verstappen [14] and Sutikno [11] in his research. While the synthesis of geomorphological approach used by Oya M., and Shigeko H [7], and Oya M [8] in examining landform lowland flooding in urban Tokyo, Japan. Neither DKI Jakarta Province almost every year there was a flood of magnitude too varied and diverse spatially and temporally in fluvial landform, fluvial-coastal, and coastal in the lower mainland Jakarta. The geomorphological approach to the synthesis approach is a form of fluvial landform. This approach can be used in the synthesis or answer any spatial-temporal problems of flooding in Jakarta and in other areas or as Dakka, Kuala Lumpur, and Tokyo in which these cities have in common morphologically fluvial landform are flat and low altitude. In this respect the findings of this study can be used as an approach to the classification of spatial and temporal variability of floods in flood prone area landform. Prone areas affected by flooding residential land use (area and dispersion) in fluvial landform.

Prone areas of flooding in beach ridge, coastal alluvial plain, and alluvial plain more breadth, depth and length than the alluvial fan. The spread of flood prone area flooding in the northwest, and northeast of Jakarta. Topography in flood prone area is located on the slope of the flood until basin flat with the surface altitude of less than 3 m above sea level. Beach ridge located in the northwest, and
northeast of Jakarta, where the tendency is landform direction perpendicular to the coastline. Distribution of flooded areas in beach ridge increasingly widespread, high and long on the slopes of the flat to very flat compared to the rather steep slope. Prone areas of alluvial flood plain are located on the north coast of Jakarta includes all the sub districts in North Jakarta area and a small sub district in the City of west Jakarta and east Jakarta bordering the sub district administration in north Jakarta. Topography in flood prone area is located on the slope of the flood flat with the surface altitude of less than 3 m above sea level. Distribution of flooded areas in coastal alluvial plain of the widespread, high and long on the slopes are flat to very flat compared to the rather steep slope (Figure 7).

**Figure 7.** Map potential and actual flood prone area in DKI Jakarta
The flood disaster in 1996, 2002 and 2007 in Jakarta is the major natural disasters that includes all the characteristics of a good flood extents, long, depth, and human victims. The flood disaster in Jakarta February 4 in 2007 resulted in damage to public facilities, social services, and the impact on economic activities and services with total losses amounting to 8.78 trillion rupiah, and the displaced population of 450 thousand people in government offices and schools [2]. According to the UNDP Indonesia [12], the last time the massive flooding in the lowlands Jakarta occurs in late January to February 4, 2007. The floods have caused 57 deaths, displaced 422 300 people to safety, building 1500 houses were damaged, and the loss of the city Jakarta from floods reaches USD 695 million, like example at central business district Bundaran HI, central Jakarta, and slum settlement area at Kampung Pulo, south Jakarta.

4. Conclusion
Potential prone area is not similar with actual prone area. Actual of flood prone area in the north, west and east of Jakarta lowland both in beach ridge, coastal alluvial plain, and alluvial plain; while the flood potential area on the slope is found flat and steep at alluvial fan, alluvial plain, beach ridge, and coastal alluvial plain in DKI Jakarta.

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