WHY THE FLOOD ALWAYS RETURN TO JAKARTA; HISTORICAL LAND USE CHANGES AND GEO-ENVIRONMENTAL ANALYSIS

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ABSTRACT

Flooding always return to Jakarta when the rainy seasons is coming. Many efforts have been done by the Provincial Government to overcome the issue. This study attempts to describe the reasons why the flood always returns through the historical land use changes and geo-environmental analysis of Jakarta Megapolitan. We employed remotely-sensed data; optical sensor for urban land use extraction information and radar sensor for geo-hydrology extraction variables. GRASS GIS open source software was used for the imagery processing. It is concluded that the poor management of land use transformation, lack management of streamsand basins, were lead to severe flood. Basins and streams extraction also shown that Jakarta is river`s city, where the water will always flow into the city. Revitalization of stream's buffer, minor streams, and basin management are priorities to avoid more suffered from floods.

Keywords: Flood, Land Use Changes, Remote Sensing, GIS, Jakarta

ABSTRAK

Banjir selalu kembali ke Jakarta ketika musim hujan datang. Banyak upaya telah dilakukan oleh Pemerintah Provinsi untuk mengatasi masalah ini. Penelitian ini mencoba untuk menggambarkan alasan mengapa banjir selalu kembali melalui perubahan penggunaan lahan historis dan analisis geo-lingkungan dari Jakarta Megapolitan. Kami menggunakan data penginderaan jauh; sensor optik untuk informasi ekstraksi penggunaan lahan perkotaan dan sensor radar untuk variabel ekstraksi geo-hidrologi. GRASS GIS perangkat lunak open source yang digunakan untuk pengolahan citra. Dapat disimpulkan bahwa buruknya pengelolaan penggunaan lahan transformasi, manajemen kurangnya cekungan streamsand, yang menyebabkan banjir parah. Baskom dan ekstraksi sungai juga menunjukkan bahwa Jakarta adalah kota river`s, di mana air akan selalu mengalir ke kota. Revitalisasi penyangga sungai ini, sungai kecil, dan pengelolaan DAS yang prioritas untuk menghindari lebih menderita banjir.

Kata kunci: Banjir, Penggunaan Lahan Perubahan, Remote Sensing, GIS, Jakarta

1. BACKGROUND

Jakarta is Indonesia capital city which is always suffered from floods during rainy season throughout its history. The floods of 1996, 2002 and 2007 were the greatest and most destructive ever recorded in Jakarta. The 2007 flood as much as 4,370 km^2 of the city was affected, displacing a recorded 500,000 people from their homes with an estimated economic cost of roads damages was US$ 15.4 million. Floods history in Jakarta is summarized in the Table 1.

Many efforts have been done by the government to overcome the floods. For example the Jakarta East Flood Canal development, that was completed in 2011. Construction of the 23.5-kilometer East Flood Canal was begun in

2003. The canal started to operate in late 2009 after it reached the Java Sea, linking five major waterways in East Jakarta: the Cipinang, Sunter, Buaran, JatiKramat and Cakung rivers.

In the year 2013, the city allocated Rp2.5 trillion (US$205 million) city budget to fund flood mitigation projects, including dredging projects and the construction of around 2,000 absorption pits. [2]

The other effort is supported by international financial institution, such as from World Bank. World Bank supports the development of canals and technical assistant for managements with the commitment amount is US$139.64 million. The name of the project is Jakarta Urgent Flood Mitigation Project. The development objective of this project is to contribute to the improvement of the operation and maintenance of priority sections of Jakarta's flood management system. There two components to the project (period 2012–2017). The first component is dredging and rehabilitation of selected key floodways, canals and retention basins. This component will support the dredging and rehabilitation of 11 floodways or canals and four retention basins which have been identified as priority sections of the Jakarta flood management system in need of urgent rehabilitation and improvement in flow capacities. The dredge material will be transported and disposed into proper disposal sites. The second component is technical assistance for project management, social safeguards, and capacity building. This component will support contracts management, engineering design reviews, construction supervision engineers for the dredging and rehabilitation works and technical assistance for implementation of the project, including the resettlement policy framework, resettlement plans and the grievance redress system. [3]

Table 1. Floods history event in Jakarta

Periods	Rivers	Main cause	Displaced	Affected area (km2)	Notes (casualties and damages)
1621, 1654, 1918, 1942, 1976	Main river	Heavy rain	No data	No data	No information

Table 1. Floods history event in Jakarta (continue)

Periods	Rivers	Main cause	Displaced	Affected area (km2)	Notes (casualties and damages)
6–9 January 1996	Ciliwung	Heavy rain	28,000	1,175	Floodwaters up to 7 meters
9-13 February 1996	Ciliwung	Heavy rain	30,000	1,190	Rainfall 5 times the normal levels, worst flooding since 1942. Tens of thousands of people left homeless, 565,000 people affected.
31 January–22 February 2007	Ciliwung, Pesangrahan and Krukut Cisadane	Heavy rain	500,000	4,370	Worst floods in Jakarta in living memory. Water up to 4 meters deep in parts of city. Jakarta 75% flooded (255 square miles under water). 340,000 homeless. Worst floods on Ciliwung river in 10 years. Damages to roads in Jakarta cost US$15.4 million. Total flood damages estimated at 8.8 trillion rupiah.
15–22 January 2013	Ciliwung, Pesangrahan and Krukut Cisadane	Heavy rain	>37,000[1]	No data	95,000 people affected[2] 23 people killed, 26,426 people minor injured
13–29 January 2014	Ciliwung, Pesangrahan and Krukut Cisadane	Heavy rain	>62,000[4]	No data	Approximately 134,662 persons or 38,672 households in 100 urban villages are directly affected by floods, with 12 casualties[4]

Source: [4]

[1]http://reliefweb.int/disaster/fl-2013-000006-idn

[2]http://edition.cnn.com/2013/01/18/world/asia/indonesia-jakarta-floods/

[3]http://www.who.int/hac/crises/idn/sitreps/indonesia_floods_sitrep_jakarta_23january2013.pdf

[4]http://reliefweb.int/map/indonesia/indonesia-update-jakarta-floods-21-january-2014

Furthermore, the other factor that makes floods more severe is the population development of Jakarta. In year 2002 population of Jakarta approximately

8.5 million people, in year 2006 increased to 8.96 million people, and in the next five years is estimated as 9.1 million people. Population density in 2002 reached 12,664 inhabitants per km^2, in 2006 reaching 13 545 inhabitants per km2 and estimated that in five years reached 13, 756 inhabitants per km^2. The rate of population growth in the period 1980–1990 was 2.42 percent per year, decreased in the 1990–2000 period at a rate of 0.16 percent. In the period 2000–2005, the population growth rate at 1.06 percent per year. [5]

The population development and population rate of Jakarta is shown the Figure 1.

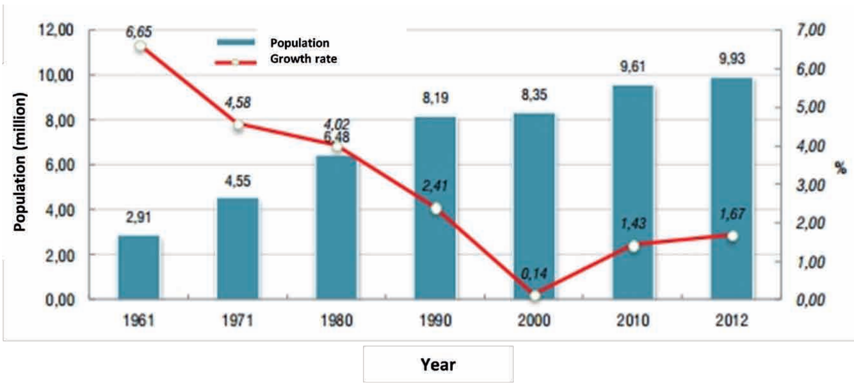

Figure 1. Population development and population growth rate of Jakarta
Source: SP 1961–2010 and Population Projection of year 2012, Statistical Bureau of Jakarta

In the year 2012 based on the population projections of Jakarta, the population was 9,932,063 people, when compared with the total population in 2011, the population of Jakarta was 9,761,992 people, and there has been an increase of 170,071 inhabitants or an increase of 0.98 percent. In the period of 1961–1990 the total population grew rapidly from 2.9 million in 1961 to 4.6 million in 1971, or 4.58 percent per year of population growth rate. Then the next ten years, the population increased again to 6.5 million people, with a growth rate was 4.02 percent per year. In 1990, the population of Jakarta increased by about 1.7 million people, bringing the total number to 8.3 million inhabitants. During the period 1980–1990 the population growth rate was 2.41 percent per year. In the period 1990–2000, the population growth of Jakarta was about 0.14 percent. And in the period 2000–2012, the population growth rate rose to 1.67 percent per year. [6]

From the population pyramid (Figure 2), the population of Jakarta has led to an aging population, means that the proportion of young population (i.e. aged 0–14 years) has begun to decline. When in 1990, the proportion of young population is still at 31.9 percent, and then in 2006 this proportion dropped to 23.8 percent. Throughout the years 2002–2006, the proportion of young age population is relatively stable, which is about 23.8 percent. Conversely the proportion of elderly population (65 years and over) rose from 1.5 percent in 1990, to 2.2 percent in 2000. In 2006, the proportion of elderly population has increased to 3.23 percent.

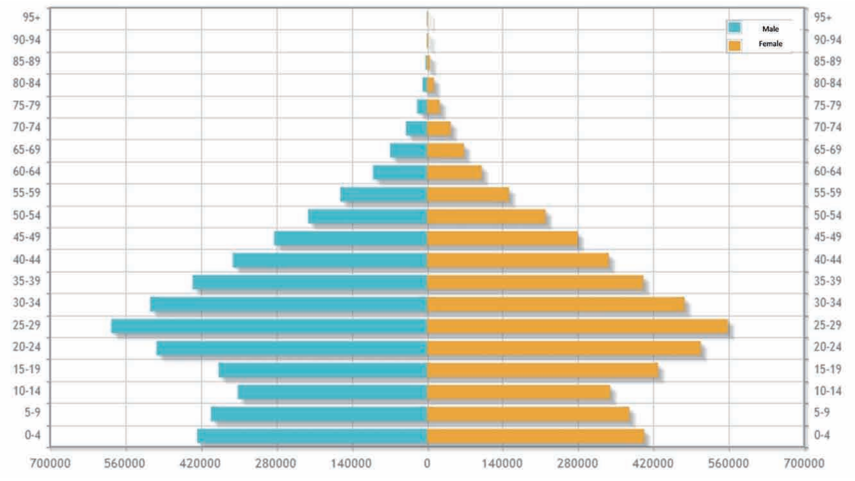

Figure 2. Population pyramid of Jakarta. Source: [7]

Flood impact on socio-economic such as damage in house and small business enterprises are countless. However, there is no preliminary research that has been conducted to get clearer figure regarding the issue.

The purposes of this study are to documentes the land use changes and geo-environmental condition of Jakarta and explain why the flood always returns. We hope this study could contribute in order to help the government efforts to overcome the floods.

Objectives

The objectives of this study are: (1) To produce urban land use changes detection from year 1982 and year 2013 of Jakarta and it`s satellite cities. (2) To extract the basins and streams map for hydrological background analysis. (3) To create elevation profile where was the flood event happened. These maps are valuable "treasures" to improve our understanding whythe flood always return to Jakarta every rainy season comes.

2. STUDY AREA

Study area is Jakarta Megapolitan Area, we subset the study area into 158,000 ha enclosed area. Located on the northwest coast of Java, Jakarta is the country's economic, cultural and political center, and with a population of 9,932,063 people in year 2012, it is the most populous city in Indonesia. The official megapolitan area, known as Jabodetabek (a name formed by combining the initial syllables of Jakarta, Bogor, Depok, Tangerang and Bekasi), is the second largest in the world, yet the megapolis`s suburbs still continue growing beyond it (ie. Depok City). This megapolitan has population of over ~30 million, making it one of the world's largest conurbations in terms of number of inhabitants. Jakarta has grown more rapidly than Kuala Lumpur, Beijing and Bangkok. "Shinjyuku" of Jakarta is new extended area of Central Business District in southern Jakarta (Figure 3)

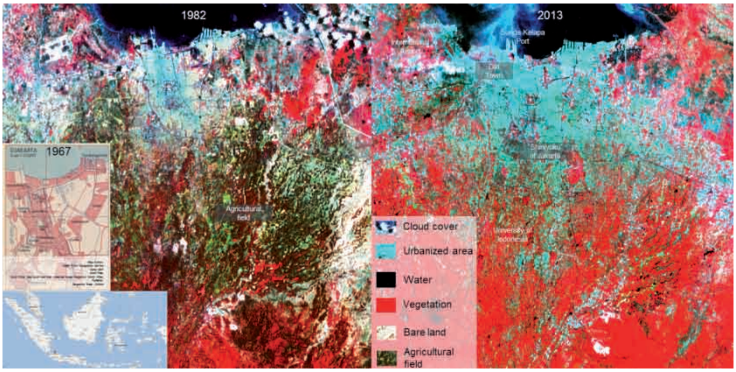

Figure 3. Transformation of Jakarta Megapolitan. Landsat 4 MMS for year 1982 and Landsat 8 OLI for year 2013

3. DATA AND METHOD

In this study we employed satellite images from Landsat family. Data used in this study is shown in the Table 2. Landsat Multispectral Scanner (MSS) images consist of four spectral bands with 60 meter spatial resolution. Approximate scene size is 170 km north-south by 185 km east-west (106 mi by 115 mi). Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. Landsat images were downloaded from http://earthexplorer.usgs.gov/.

Table 2. Data used in the study

Satellite image	Index	Acquisition	Band used	Wavelengths (micrometres)
Landsat 4MSS	P131 / R64	October 3rd, 1982	Band 4, 5, & 6	0.5–0.8
Landsat 8OLI	P122 / R64	August 25th, 2013	Band 4, 5, & 7	0.64–2.29

The Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) was developed jointly by the METI (Ministry of Economy, Trade, and Industry) of Japan and the NASA (National Aeronautics and Space Administration) of United States. The ASTER sensor was launched onboard NASA's Terra spacecraft in December 1999. The spatial resolution of generated DEM is 30 m. It covers land surfaces between 83°N and 83°S (ASTER GDEM Readme Handbook). The absolute vertical accuracy of ASTER GDEM version-1 is 20 m at 95% confidence level. The improved vertical accuracy of ASTER GDEM version-2, released on October 17, 2011, is 8.86 m (ASTER GDEM V2 validation report). For this study, ASTER GDEM version-2 was downloaded from http://gdem.ersdac.jspacesystems.or.jp/index.jsp

Methodology of this study shows in Figure 3. We used open source software, GRASS GIS and Quantum GIS for imagery processing and DEM processing for basins and streams extraction.

Pre-processing, such as radiometric and atmospheric corrections, which are necessary for analysis of land use/land cover parameters, was conducted. The Landsat 3 MSS and 8 OLI sensors store information as digital numbers (DNs) in the range of 0 to 255. We convert these DNs to ToA reflectance. We chose the spectral value method of classification to extract a land use map from color composite images. We employed 465 band combination for Landsat 3 MSS and 754 band combination for Landsat 8 OLI. We defined two classes for the urban land use map (Fig. 1): urban (man-made structures including builds, roads, and all impervious objects) is represented in red and another land use area (including dense and sparse vegetation, water bodies, and agricultural fields) is represented in white.

GRASS GIS software is open source software that has been equipped with the command console and watershed module to extract the basins and streams. The land use classification was done by supervised classification maximum likelihood module. The basic element for deriving basins and streams map is the digital elevation model (DEM). It can be derived from ASTER GDEM with 30m of ground resolution. For final cartography design we employed Quantum GIS open source software which has been integrated with the GRASS GIS.

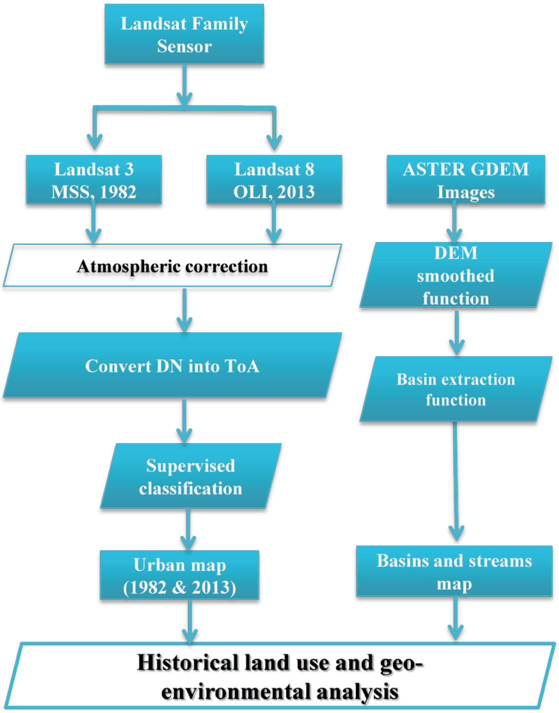

Figure 4. Methodology

Classification technique was employed using the"gi.maxlikh" module in GRASS GIS. To generate statistics from training area, the "gi.gensigh" module is being used. In the classification method, we need to make group that contain the raster imageries. The "gi.grouph" module then used to select all relevant bands of the raster imageries. The final result of urban land use than converted into vector format by the "r.to.vect" module.

Before we extracted the basins and streams, we performed a neighborhood filter using the mean operator to smooth the ASTER GDEM image. This method was done using the "r.neighbors" module. The "r.watershed" module then employed to extract basins and streams. We used 10,000 threshold and 700 threshold to extract main basins, streams basin, sub-basins, and sub streams respectively.To calculate the basin coverage area we employed the "v.db.addtable", "v.db.addcol" and "v.to.db" module. The basic concepts in calculation feature area (polygon) in GRASS GIS are; build the database, create a new table, and column, and input the information.

The "Point Sampling Tool" plugin in Quantum GIS was used to extract elevation values from a raster layer of ASTER GDEM image based on a vector point of floods event year 2013.

4. RESULT AND DISCUSSIONS

For year 1982, the urban development concentrated in the northern and center part of Jakarta (Figure 4), while in the northwest, northeast, and southern part was dominated by agricultural fields.

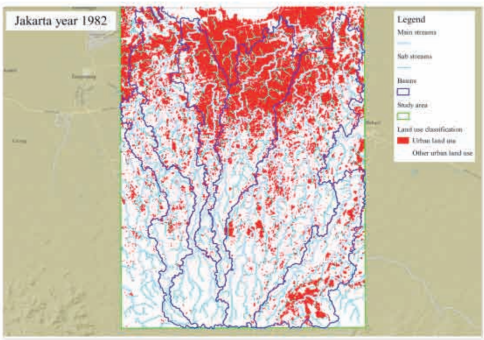

Figure 5. Urban land use map of Jakarta for year 1982

Agricultural fields and green space play a main role in order to catch the water when the rainy season comes. Sub streams also play a role as a place for water flow from the higher elevation to the lower elevation and send the water to the main streams. Upper-streams region in year 1982 was dominated by agricultural fields and dense to sparse vegetation cover.

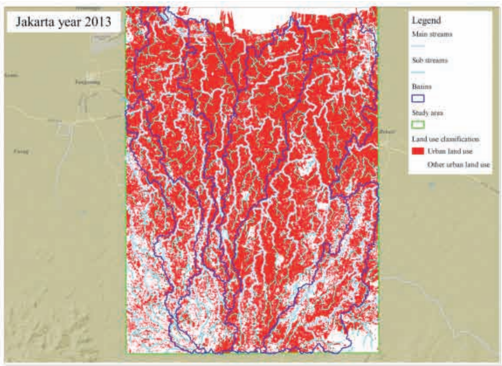

Figure 6. Urban land use map of Jakarta for year 2013

For year 2013, Jakarta lost most of its sub streams because of population increase that influence the higher demand of settlements. Unfortunately, migrants chose the river-side environment as their settlements. Agricultural fields in the upper-streams region in the southern part than transform into impervious surfaces. The place for water was occupied by man-made structures then lead to heavy floods when rainy seasons come.

In Jakarta, river-side environments are in bad condition. From the assessment using remotely-sensed image we can see that there is no buffer zone available (Figure 6). Uncontrolled development can be seen from the density of man-made objects along river-side.

Uncontrolled development and transformation within inner city and satellite cities was identified from satellite images. Especially the river-side environment, there are no reservation of precious waterside areas along river-side (Figure 6). There are no improvement and development of minor rivers to protect Jakarta from suffered serious damage of floods.

From the basins and streams extraction we can understand that Jakarta is the river's-city. There are many main streams consists of many sub streams flow through the city. Miss management of main streams, sub streams, and great basin surrounding megaurban leads to huge amount of surface run-off those cause heavy floods. At least there are six basins covered Jakarta and it`s satellite cities. These six basins play main role to create the floods. The coverage areas of every six basins in Jakarta are shows in Figure 7.

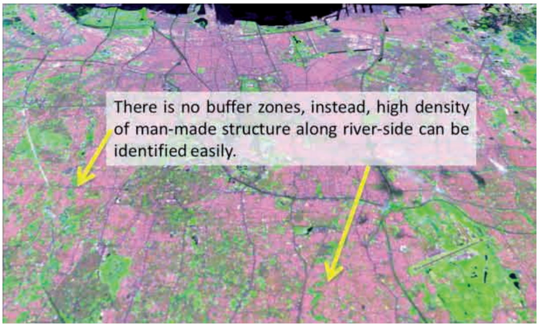

Figure 7. There is no buffer zone along river-side

Figure 8. Coverage areas of six basins in Jakarta extracted from ASTER GDEM

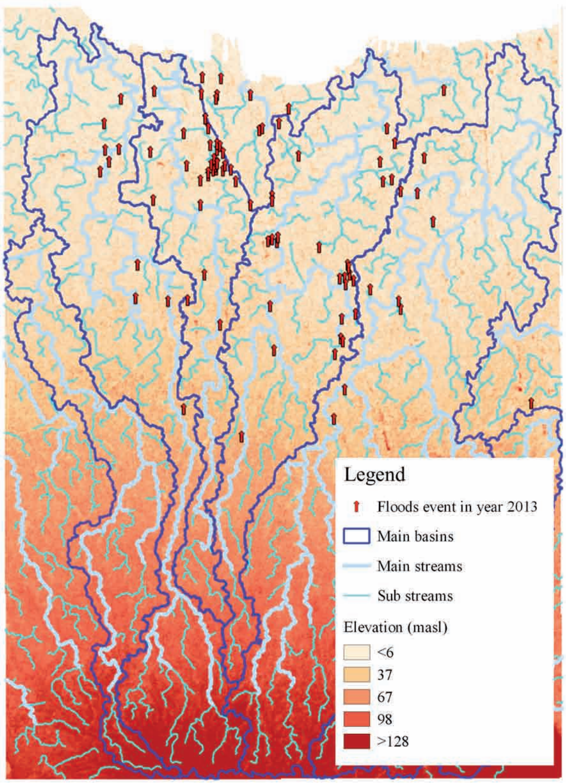

Figure 9. Flood event distributions for year 2013
Source of floods event:http://www.google.org/crisismap/2013-jakarta-flood-en?no_redirect=true

From Figure 8 we have more understanding that floods event was associated with lower elevation physical environment (5–52 meter above sea level) and floods happened near the main and sub streams. Furthermore, Figure 9 gives us deeper analysis in floods event distribution based on elevation profile.

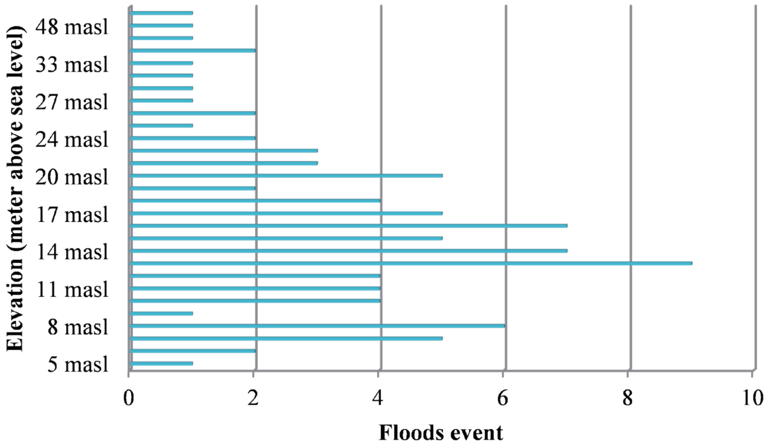

Figure 10. Floods event distribution based on elevation. Floods event year 2013 used as based to extract elevation values from ASTER GDEM image

From the Figure 9 above, floods was happened mostly in elevation between 8 meter to 20 meter above sea level. The streams characteristic also inform us that the geomorphology of Jakarta is alluvial lowland plan. A dendritic drainage pattern was identified from the streams extraction of ASTER GDEM. A dendritic drainage pattern is the most common form and looks like the branching pattern of tree roots. It develops in regions underlain by homogeneous material, in the Jakarta case is alluvial soil forms. Jakarta alluvial lowland plan was created by the deposition of sediment over long period that coming from highland regions. The source of the alluvial material is from upper streams in the southern part of Jakarta.

5. CONCLUSIONS

Dramatically land use changes from 1982 to 2013 were identified and river-side suffered from impervious surface developments. Urban transformation in the inner city and the development in the satellite cities which is also play a role as the upper streams region of Jakarta's basins, have a direct relationship with the water flows that leads to flooding.

From basins and streams extraction it can be understood that Jakarta is river`s city. There are many main streams and sub streams flow through the city and there are six main basins covered the city and satellite cities. The geomorphology of Jakarta is alluvial lowland plan, which is means the water will always flow into the city.

Flooding will always return to Jakarta since the basins and streams management is poor. Land use changes should be appropriate with the spatial plan, and it is needed law enforcement. Urban green space and river-side management need to get more attention.

Recommendations

Revitalization of stream's buffer, minor streams, and basin management are priorities to avoid more suffered from floods. Law enforcement in spatial planning implementation is needed. More effort in northern part is needed since the rise of sea level will leads to flood. The UNEP Intergovernmental Panel on Climate Change concludes that sea rise from global warming will permanently inundate large areas of major urbanized regions of Asia, and heavy precipitation events will continue to become more frequent over of the world throughout the 21st century. [8]

Furthermore, the most difficult part is how to re-settle thousands of urban inhabitants from river-side environment? Education is the keyword. Urban inhabitants need to be educated about the importance of buffer area along the river-side. It will take long years, but it can begin now. Provincial government has to buy the lands that occupied by impervious surface and then returning the function into the urban green space.

Coordination between Jakarta`s government and the governments of its satellite cities need to optimized based on the basins that covered the administration areas.

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