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Urgent Measure of Geospatial Parameters for Flood Modeling in Indonesia

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Abstract*—Indonesia is prone to flood. Many areas including cities have a suffering flood in history until these recent days. Jakarta city, for example, had suffering flood since Dutch colonial time a few hundred years ago and even earlier until this recent year 2018. Besides Jakarta, Indonesia has other big cities like Bandung, Semarang, Surabaya and Medan which frequently suffered from the flood. Growing cities like Langsa, Pekanbaru, Palembang, Pamanukan, Garut, Cirebon, Pekalongan, Demak, Bojonegoro, Banjarmasin, Gorontalo, Bima are also suffering flood in almost regularly. The flood condition is different from time to time due to rain intensity and rivers capacity are leading to disaster. Low land areas such as coastal areas and peatland areas in many regions of Indonesia are experiencing the same disaster. Adaptation and mitigation should be taken against this flood disaster. In order to find the best adaptation and mitigation, first, we must understand the characteristic of the flood by creating flood models. Essential parameters of flood modeling would include geospatial parameters (e.g., Digital Elevation Model, Land use, and rivers geometry). Unfortunately for Indonesia's case, these geospatial parameters of the flood are still relatively weak. We can see that several flood models of Indonesia are in low accuracy spatially and temporarily. So, the measure of geospatial parameters is urgent. This paper will highlight this urgency.

***Keywords*— flood; adaptation; mitigation; geospatial parameters.**

I. INTRODUCTION

One of the most frequent disasters in Indonesia is a flood (figure 1). Many areas, including cities, coastal areas, peatland and other low land areas, have a suffering flood in history until these recent days. Jakarta city, for example, had suffering flood since Dutch colonial time a few hundred years ago and even earlier until this recent year 2018.

Fig. 1 Pictures example of flood happened in regions of Indonesia [1]

Besides Jakarta, Indonesia has other big cities like Bandung, Semarang, Surabaya, and Medan, which frequently suffered from the flood. The depth of the flood can be from foot height until 2-3 meters, while the area can be localized or as large as the district size [1], [2] although the flood condition is different from time to time due to rain intensity, and rivers capacity. Nevertheless, all of them are producing real disaster with real losses.

Figure 2 shows a record of floods happened in regions of Indonesia, including estimation of the effected number of people from 2000 to 2010 in a map [3]. Accumulation of rainfall also is plotted on the map during those periods. Base on the investigation, a total of people who are at risk of the flood might who 3,780,000. Java Island has the highest number of places suffering flood as well as the highest value of affected people in this historical record, followed by Sumatera Island. It seems the development area and people concentration have a positive correlation with flood existence. Degradation on the environment (e.g., deforestation, decreasing of infiltration, and increasing of runoff) due to development and people concentration, it might be the most significant causes derived from the flood. The highlight of flood mechanisms and their causes can be seen in the next chapter.

Fig. 2 Record location of flood happened in regions of Indonesia, including estimation affected the number of people from 2000 to 2010. The most prominent red dot represents the affected population of nearly 600.000, while the smallest one around 10.000. The blue variation shows the accumulation of rainfall from 1.800 to 10.000 millimeters per second [3].

Table 1 shows a summary of affected facilities from the flood in Indonesia from 2000 up to 2010. Facilities are being affected mostly the houses, schools, health facilities, rice fields, forests, fish ponds, and irrigation. Other facilities are bridges, roads, and worship places. With such facilities are being affected, losses in the economy approximately reached US$ 705.7 million only from 2000 to 2010 [3]. If we noted that flood is happening for more than a century, the losses would be tremendous.

TABLE I
SUMMARY OF AFFECTED FACILITIES FROM THE FLOOD IN INDONESIA SINCE 2000-2010 [3]

No	Facilities	Unit number of affected (damage, severe and totally)
1	Houses	673.202
2	School	3.235
3	Health Facilities	1.489
4	Rice fields	91.254,6 Hectares
5	Forest	1194 Hectares
6	Fish pond	12.395 Hectares
7	Irrigation	67

The one main reason Indonesia prone to flood is due to geographical position along the equator, which favored the high intensity of rain to come. The rain generally comes during the wet season of April to September. On the other hand, millions of low lands existed in Indonesia. Table 2 shows a summary of the location and various times of flood surrounding Indonesia from 1979 up to 2009 [4]. A total of flood suffering in this country is 2.509 times during those periods. It is an enormous number, indeed. If we were considering the recent years of flood occurrences, in this case, the number would be even more massive.

As mentioned earlier, the city like Jakarta, Bandung, Semarang, Surabaya, and Medan have been suffered frequent of the flood. The growing cities like Langsa, Pekanbaru, Palembang, Pamanukan, Garut, Cirebon, Pekalongan, Demak, Bojonegoro, Banjarmasin, Gorontalo, and Bima are also suffering flood in almost regularly. Many of flood also comes on farming and fishpond area of millions of hectares. It is a severe problem for Indonesia. It is one of most disasters after the earthquake.

TABLE II
SUMMARY LOCATION AND FREQUENT TIMES OF FLOOD SURROUNDING INDONESIA FROM 1979-2009 [4]

No	Province	Frequent times of flood from 1979 to 2009
1	Bali	**16**
2	Banten	**66**
3	Bengkulu	**19**
4	DI Yogyakarta	**18**
5	DKI Jakarta	**62**
6	Gorontalo	**25**
7	Jambi	**84**
8	Jawa Barat	**248**
9	Jawa Tengah	**337**
10	Jawa Timur	**278**
11	Kalimantan Barat	**73**
12	Kalimantan Selatan	**132**
13	Kalimantan Tengah	**53**
14	Kalimantan Timur	**63**
15	Kep. Bangka Belitung	**6**
16	Lampung	**72**
17	Maluku dan Maluku Utara	**13**
18	Nusa Tenggara Barat	**53**
19	Nusa Tenggara Timur	**99**
20	Papua dan Papua Barat	**23**
21	Pemerintah Aceh	**138**
22	Riau dan Kepulauan Riau	**48**
23	Sulawesi Barat	**13**
24	Sulawesi Selatan	**130**
25	Sulawesi Tengah	**55**
26	Sulawesi Tenggara	**41**
27	Sulawesi Utara	**20**
28	Sumatera Barat	**96**
29	Sumatera Selatan	**53**
30	Sumatera Utara	**175**

Adaptation and mitigation should be taken against this flood disaster in Indonesia regions. In order to find the best adaptation and mitigation, first, we must understand the characteristic of the flood by creating flood models. Essential parameters of flood modeling would include geospatial parameters (e.g., Digital Elevation Model, Land use, and rivers geometry).

Unfortunately for Indonesia's case, these geospatial parameters of the flood are still relatively weak. We can see that several flood models of Indonesia are in low accuracy spatially and temporary. In the next section, we discuss how the model limitation. So, the measure of geospatial parameters is urgent if we expect better adaptation and mitigation, and this paper highlights this urgency.

II. Materials and Method

As mentioned in the aim of this paper, we will highlight the urgency of geospatial parameters for flood modeling in Indonesia. This subject arose due to a lack of geospatial data availability so we can create a good flood model. Without a good model, we would find difficulties in creating good adaptation and mitigation of flood disasters in Indonesia. The data and method we collect and do in this paper are merely listing the need for flood parameters, including geospatial parameters and why they are necessary. We give an example of sound flood modeling generation (e.g., using accurate river geometry, accurate Digital Elevation Model, primary data of rain intensity, and soil parameter). We describe the existing model flood of Indonesia with such limitation of accuracy due to lack of data availability. The consequences of the lack of good data availability are briefly explained. For that case, we can firmly conclude the urgent measure of geospatial parameters for flood modeling in Indonesia. However, first, we start with the theoretical background of the flood.

From the hydrological cycle, the water from the troposphere will go down to the earth by the rain. The massive volume of water (depend on rain intensity) will be distributed to the river and retention area (e.g., a lake, irrigation) through runoff and into the ground below through infiltration. Flood will occur if the river and retention area cannot take the capacity of water coming to their volume capacity [1]. Land use and land cover will influence the infiltration and runoff, as well as erosion, create sedimentation on the river and retention area. This sedimentation will decrease their capacity. So, when the rain comes to the area with low infiltration and high runoff and erosion and limited river geometry and retention, in this case, the flood will most likely happen.

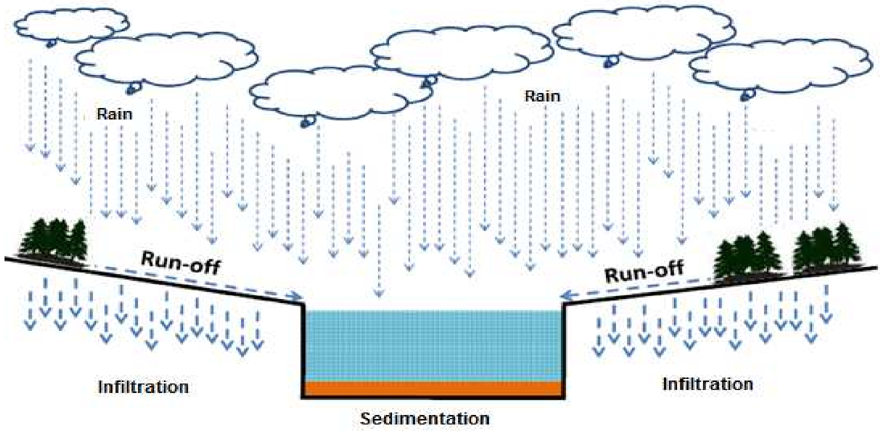

Fig. 3 Illustration of flood occurrence. From the hydrological cycle, the water from the troposphere will go down to the earth by the rain. The massive volume of water (depend on rain intensity) will be distributed to the river and retention area (e.g., a lake, irrigation, etc.) through runoff and into the ground below through infiltration. Flood will occur if the river and retention area cannot take the capacity of water coming to their volume capacity.

From the flood theory, we can understand in order to create flood models. It is necessary to have information such as rain intensity, Digital Elevation Model (DEM), river geometry, retention, land use, land cover, soil parameters, and other necessary hydrometeorological data. If from areas existed flood, we can earn an inundation map. It would be beneficial for model validation. Some technology (including the satellite) may involve in these data acquisition with such accuracies. From land use and land cover, we can estimate infiltration parameters and runoff coefficient. We may also create a sedimentation model from land use together with soil properties information. If all these parameters are successfully being collected, therefore we would create a good flood model. This model will be useful for mitigation, landscape modeling as well as for early warning (see figure 4 for the scheme).

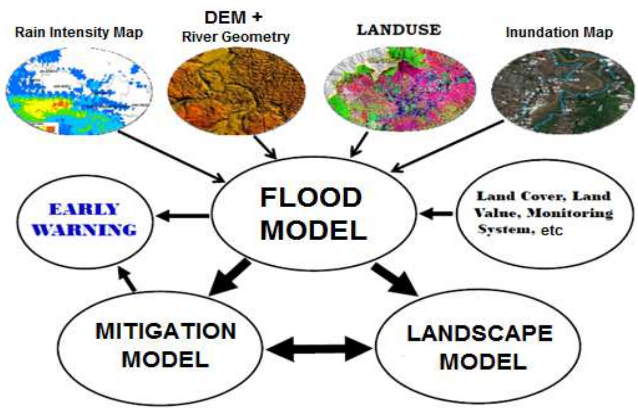

Fig. 4 Diagram represent parameters of flood modeling and the usefulness of the good flood model for mitigation model, landscape model, and early warning

Best data of rain intensity can be collected from field measurements using the sensor. Nevertheless, many stations need to install around the watershed areas and even regional basins. This seems quite costly, so for Indonesia's case, the availability is still entirely reduced until recent days. Data from satellite (e.g., TRIMP) can help us to get information but with low spatial and temporal accuracy. This limitation of rain intensity data may degrade the flood model accuracy, respectively.

To find the best capacity of river and retention, including the topographic area of the watershed, we need a good DEM model and river geometry. So far, the best DEM creation comes from leveling data. Nevertheless, with such a substantial geographical of Indonesia, this leveling measurement is time and cost consuming and, in a situation, it would not be visible. Photogrammetric and LiDAR technology with few decimeters' accuracies is today the best technology in generating DEM suitable for flood modeling. This technology at some point is still quite expensive, but for understanding flood, it seems worthy. Nearly in the future UAV will be a good alternative. The low accuracy of DEM, which is distributed freely, comes from satellite measurement (e.g., SRTM).

Best data affordable with such required accuracy is a high-resolution satellite image to define land use and land cover. For creating the Indonesian flood model, these data are already existed and even with quite a complete time series. Nevertheless, without support from other data, the creation of a good flood model would still be homework. In chapter result and discussion, we will see an explanation of the available product of the flood model of Indonesia which is recognized in low accuracy. We give examples (figure 5) of such a detail grid of flood model, which was happening in Garut city 2016.

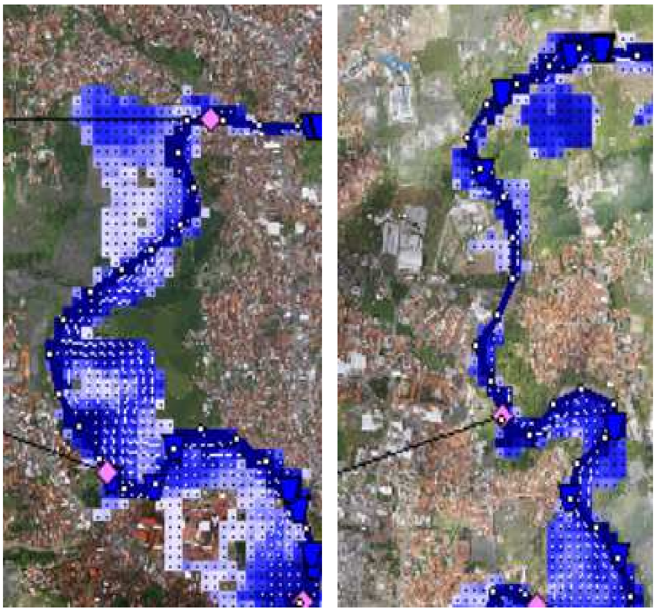

Fig. 5 Pictures example of flood modeling for Garut city in 2016. The model generated from well available flood parameters such as rain intensity, DEM, river geometry and inundation map. The detail grid of the flood model was successfully created with quite a reasonable accuracy.

The model was created with such quite good accuracy. After the flood happening in the area, we immediately surveyed the inundation forensic in order to derive the inundation map for model accuracy validation. We use DEM from UAV and TLS (Terrestrial Lase Scanner) survey, the geometry of the river from cross-section survey, and rain intensity from combination Insitu Stations and Satellite Trimp data. For data land use and land cover, we use a combination of LANSAT and UAV. Runoff coefficient and infiltration parameters can be extracted from these data together with the availability of physical parameters such as soil properties.

III. Results and Discussion

There are several published flood models of Indonesia, including the one published by National Disaster Management Authority; it is an Indonesian government agency that manage disaster response and mitigation. The model has an attractive look (see figure 6) but, unfortunately, with very low accuracy. Data flood parameter that is being used only Digital Elevation model extracted from SRTM while others like rain intensity, rivers geometry, retention remain unclear. Either the data is too expensive or else, it seems effort in making them available is far beyond expectation. However, if we see US$ losses from flood disasters in Indonesia, data of flood parameters (especially the geospatial data) indeed is not expensive as it was. It is just a matter of willingness after all.

If we cannot create a good model of a flood, it is challenging to create a good model for adaptation and mitigation. The model can be too optimistic or underestimate. The execution of adaptation and mitigation base on the model can be miss leading as well as cost-ineffective. Not to mention if we calculate the risk to people, a low accuracy model might add the risk. Underestimate of risk would lead to severe losses to the people if they turn out the risk is indeed very high. So, creating a good flood model indeed is very necessary with such proper data parameters like geospatial parameters of DEM, river and retention geometry, land use land cover and sediment model.

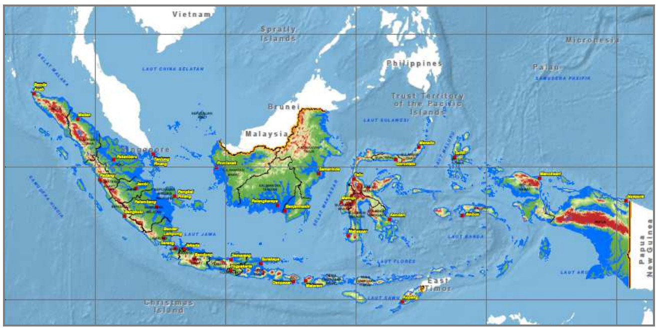

Fig. 6 Flood model risk of Indonesia updated in the year 2010. Places of high risk colored by blue. Almost all low land area of Indonesia categorizes as high risk [4]

In order to highlight the lack of proper data parameters for flood modeling (especially geospatial data) in Indonesia, we did investigate through publications, the internet, and including personal communication with experts (5) and authorities (3). Table 3 summarizes our findings. Only land use and land cover that is available with such good quality while the others have low resolution and many are relatively weak availability. Here we urgently need to measure flood parameters especially geospatial parameters for better flood models of Indonesia.

TABLE III
SUMMARY OF DATA'S FLOOD MODEL PARAMETER AVAILABILITY FOR INDONESIA CASE

No	Flood model parameters	Data availability for Indonesia case
1	Rain intensity	Low-resolution data
2	Digital Elevation Model	Relatively poor
3	River Geometry	Relatively poor
4	Retention area	Relatively poor
5	Land use land cover	Relatively good
6	Flood inundation map	Limited data
7	Runoff parameters	Relatively poor
8	Infiltration coefficient	Relatively poor
9	Sedimentation model	Relatively poor

To convince the urgent need of data to respond to the lack of availability of good flood models in Indonesia (especially concerning geospatial parameters) here, we make a comparison of two models created for Jakarta. One model is based on specific data parameters, while others based on limited data. The specific parameters will include DEM from LiDAR which has the accuracy of 40-centimeter, detail geometry of rivers especially for Ciliwung Rivers, Kanal Barat Flood, Cengkareng Drain, and some tributaries [1]. We can see a significant difference in the result (see figure 7). Cluster areas of a flood can be identifying base on the accurate models as well as floods along the rivers. Meanwhile, the inaccurate model was leaving quite a significant uncertainty.

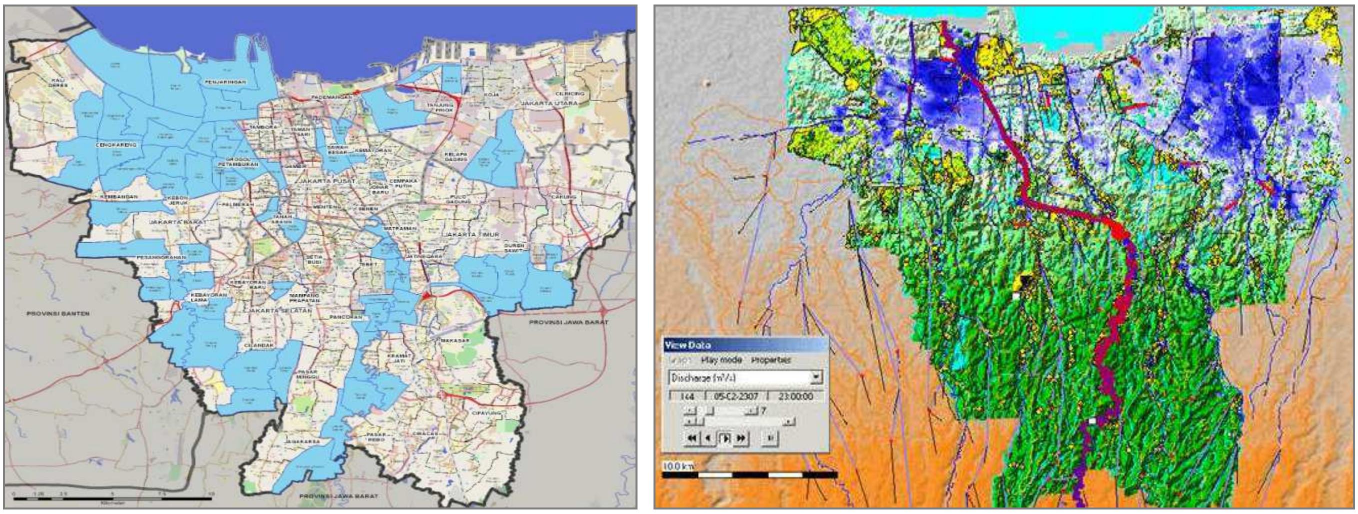

Fig. 7 Two models of flood in Jakarta for the period 2007 using two different set parameters. One model is based on specific data parameters while others based on limited data. We can see a significant difference in the result [1], [4].

We make comparison also for flood models around Bandung. The similar scenario applied, one model, is based on specific data parameters while the others based on limited data. The specific parameters will include DEM from photogrammetric which has an accuracy of 20-40-centimeter, detail geometry of rivers especially for Citarum and some tributaries [2]. We can see a significant difference in the result (see figure 8). A detail cluster area of a flood can be identifying base on an accurate model. Meanwhile, the inaccurate model was leaving quite significant uncertainties and problems for disaster response, adaptation, and mitigation, respectively (e.g., missed identification of right flood area and vice versa).

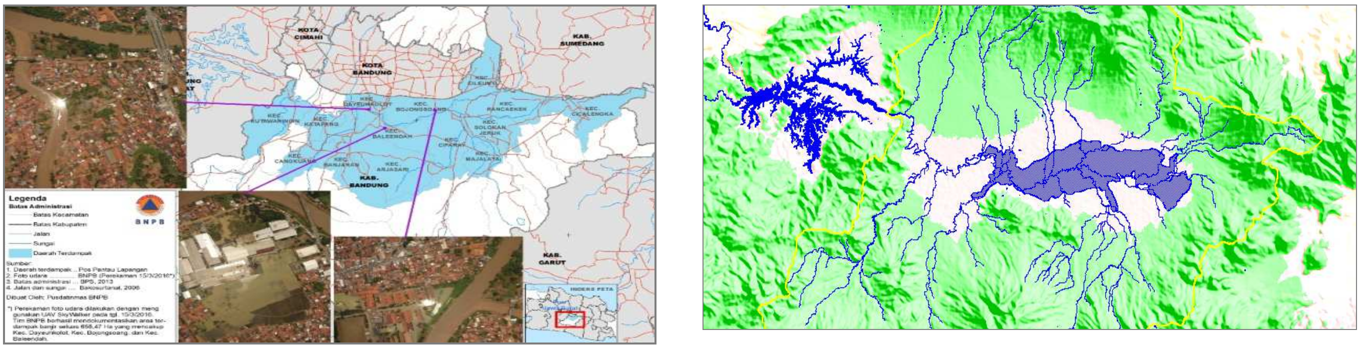

Fig. 8 Two models of flood in Bandung using two different set parameters. One model is based on specific data parameters while the others based on limited data. Clearly, we can see a significant difference on the result [1], [4]

Urgent need for specific parameters to create a good flood model, especially the geospatial parameters are proven for our country Indonesia. Noted again that if we see US$ losses from flood disasters in Indonesia, data of flood parameters (especially the geospatial data) indeed is not expensive as it was. It is just a matter of willingness after all. Tables 4 summarize data recommendations from selected technology to fulfill geospatial data parameters for good flood modeling.

DEM can be derived from LiDAR and large-scale photogrammetric survey. At least Big cities in Indonesia that are prone to floods need to be surveyed by LiDAR. Today, LiDAR is only available for Jakarta, Medan, Tanggerang, Bekasi, and Surabaya. River geometry can be derived from cross-section measurements using a combination of bathymetry and RTK GNSS. At least big rivers (e.g., Citarum, Bengawan Solo, Musi, Brantas, and Kapuas) need to be surveyed.

TABLE IV
SUMMARY DATA RECOMMENDATION FROM SELECTED TECHNOLOGY TO FULFILL GEOSPATIAL DATA PARAMETERS FOR GOOD FLOOD MODELING IN INDONESIA

No	Geospatial data for flood model parameters	Data recommendation from selected technology
1	Digital Elevation Model	LiDAR (only available for today: City of Jakarta, Medan, Tanggerang, Bekasi, and Surabaya) Large scale photogrammetric (only available for Today: City of Bandung)
2	River Geometry	Cross-section using RTK and bathymetry
3	Retention area	Bathymetry
4	Land use land cover	High resolution of satellite images (already available for all regions of Indonesia)
5	Inundation map	Photogrammetric or UAV after flood existence
6	Sedimentation measurement	Time series bathymetry

Somehow the acquisition of geospatial data for flood modeling needs to be done. Who responsible for this acquisition, of course, is Government? Nevertheless, many institutions in the Government body can sometimes be mixed in their responsibility. Here highlight in table 4, we propose institutions in charge of geospatial data in order to support good flood models for better adaptation and mitigation as well as for quick disaster response. The leading institution involved is Indonesia Geospatial Agency (BIG), Ministry of Public Works (Kementrian PU), LAPAN, and National Board for Disaster Management (BNPB). Other institutions may support the leading institutions.

TABLE V
PROPOSE INSTITUTIONAL IN CHARGE OF GEOSPATIAL DATA ACQUISITION TO SUPPORT FLOOD MODELING

No	Geospatial data for flood model parameters	Institutional In charge of data acquisition
1	Digital Elevation Model	Indonesia Geospatial Agency (BIG)
2	River Geometry	Ministry of Public Works (Kementrian PU)
3	Retention area	Ministry of Public Works (Kementrian PU)
4	Land use land cover	LAPAN
5	Inundation map	National Disaster Management Authority (nation)
6	Sedimentation measurement	Ministry of Public Works (Kementrian PU)

We can look at our neighbor countries like Singapore, Malaysia, and the Philippines as an example of their geospatial program in supporting flood modeling. The philippine is already doing the LiDAR for all the Islands and measuring river geometry for all main rivers, etc. Malaysia is now ongoing to do the LiDAR for the whole area also and not to mention Singapore. Of course, Indonesia is the biggest country among them. More effort needs to be prepared and done. However, with such resources that existed in our country, we can do an even better program.

As for the final discussion here, we need to note the latest research finding that concludes how the land subsidence and the sea level rise [5]–[8] also affected significantly to the flood occurrence. Land subsidence may change the DEM, further changing the flood behavior. For the case of the coastal areas, a flood can be worsening by the sea level rise hit the coastal low land areas. It means that degradation on the environment (e.g., deforestation, decreasing of infiltration and increasing of runoff) due to development and people concentration along with land subsidence and the sea-level rise; it might be the most significant causes derived the flood by the end of the day. The time scale of flood phenomenon, land subsidence, and sea-level rise can be unified by interpolation and extrapolation.

Geospatial technology luckily can see the land subsidence and the sea level rise phenomenon [9]–[14] accurately. Indeed, even some available good flood model still needs to be corrected for the land subsidence (e.g., to their DEM and river geometry). So, in other words, the urgency of this paper's subject is even more.

IV. CONCLUSIONS

It is undeniable that many areas, including cities, coastal areas, peatland and other low land areas in Indonesia, have suffering flood in history until these recent days. The one main reason Indonesia prone to flood is due to geographical position along the equator, which favored the high intensity of rain to come. Since many facilities are being affected (e.g., the houses, school, health facilities, rice field, forest, fish pond, irrigation, bridges, road, worship places, etc.), losses in economy approximately have reached US$ 705.7 million for only from 2000 to 2010. OCHA release victim by flood in Indonesia. From 2000 to 2010, 1,574 people killed, 156,815 injured and missing, 3,784,279 evacuated while 11,349,529 affected. Note that flood is happening for more than a century. So, the losses would be tremendous already.

Adaptation and mitigation should be taken against this flood disaster in Indonesia regions. Losses need to be reduced or even avoided if we could. In order to find the best adaptation and mitigation, first, we must understand the characteristic of the flood by creating flood models. Essential parameters of flood modeling would include geospatial parameters (e.g., Digital Elevation Model, Land use, and rivers geometry). Unfortunately for Indonesia's case, these geospatial parameters of the flood are relatively still weak. We can see that several flood models of Indonesia are in low accuracy spatially and temporarily.

So, the measure of Geospatial parameters is urgent if we expect better adaptation and mitigation. Urgent need for specific parameters to create good flood models, especially the geospatial parameters, are proven for our country

Indonesia by this paper. Data of flood parameters (especially the geospatial data) indeed is not expensive as it was; it is just a matter of willingness after all.

As mentioned, we propose institutions in charge of geospatial data in order to support good flood models for better adaptation and mitigation as well as for quick disaster response. The leading institution notices involved Indonesia Geospatial Agency (BIG), Ministry of Public Works (Kementrian PU), LAPAN, and National Disaster Management Authority (BNPB) with help from other institutions. Our neighbor country, like the Philippines, can be an example. They are already doing the LiDAR for all Islands and measuring river geometry for all main rivers, etc.

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