MAPPING AND ECONOMIC IMPACT ANALYSIS OF FLOOD ON RICE FIELD IN UPPER CITARUM WATERSHED, INDONESIA

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ABSTRACT: Flooding events in the Citarum basin not only hit the local settlements, but also damaging rice crops and other infrastructures located in the national rice production centers in the north coast of West Java. Therefore, these losses then affect the national rice production which destabilize food security. The purposes of this study are to analyzing the characteristics of river flow and flood discharge of Upper Citarum, preparing inundation maps of Upper Citarum in the scale of 1:100,000 with return flood period scenario of 2, 25 and 100 years, and analyzing the potential for rice crop losses caused by the flood and inundation in the upper Citarum river basin, West Java. Flood return period was calculated based on the Gumbel frequency. Flood and inundation was modeled using HECRAS which was developed by the U.S. Army Corp of Engineers (2002). While the rice crops losses by the flood and inundation was estimated using RENDAMAN.CSM model. Potential loss of rice due to floods in the paddy fields on a two-year return period reached 8.4 billion rupiah (USD $ 700,00) , this amount will be tripled in the 25 years flood return period and becomes 6.4 times in the 100-year return period. Paddy spikes loss ratio of the period of 25 years to 100 years is higher than 2-year period to 25 years. This is because flood-prone areas in the 100-year return period not just located in the same area of 25-year flood return period but also includes the wetland area with water levels in between 55 to 110 cm. Losses in this area is higher compared to the losses of 25-years flood return periods.

Key Words : Flood Mapping, Hydrodynamic Model, Rice Crop Losses Model, Citarum Watershed

1. INTRODUCTION

1.1 Background

Citarum is classified as a watershed that has suffered severe damage and was always troubled by floods. Rajab (2010) states almost every year there would be flooding in the region, especially in the Upper Citarum Basin area of Bandung. Whenever events Citarum floods of not only residents but also struck settlements damaging rice crops in national rice production centers in the north coast region of West Java and other infrastructure with no small degree of loss. In high intensity and frequency of course this could affect the country's rice production will ultimately destabilize food security.

Management and flood management efforts in the watershed area is long done, but flood-prone area maps as map-based work-based high-resolution image of the hydrodynamic models (based on the average water discharge dynamic) are not yet available. Therefore, the potential maps flood-prone areas in the Citarum Hulu with this approach is an urgent necessity.

1.2 Objectives

1) Develop maps flood-prone in Upper Citarum, through 2 and 25 years of flood return period scenario
2) Analyze the potential loss of rice plants caused by flooding and inundation in the upper Citarum

2. METHODOLOGY

2.1 Time and Place

The experiment was conducted in January 2012 to end of April 2012 on the Upper Citarum watershed area includes District Dayeuhkolot, Bojongsoang, Ciparay, Baleendah, and Majalaya Bandung regency, West Java, Indonesia.

2.2 Materials and Tools

1) Daily discharge data, daily rainfall and climate data in upstream Citarum Watershed
2) Soil physics data and physiology data of Ciherang and Inpara rice variety
3) Flood events data in the last 10 years of Citarum River
4) ALOS-AVNIR Satellite Data Imagery of Citarum in 2010
5) Digital Topographic Map of Citarum Watershed, scale of 1:25.000
6) ACDP/Echo sounder, Geodetic GPS, Total Station
7) HEC-RAS software, HEC Geo-RAS, ENVI 4.3, Arc GIS 10.0 and plant model (RENDAMAN.CSM)

2.3 Stages of Research

Research activities carried out in five sections, namely: determination of flood discharge and return period, the preparation of DEM, land cover map preparation, preparation of flood maps along with the repetition period of validation and counting the rice crop losses due to flooding events. The stage of research presented by Figure 1.

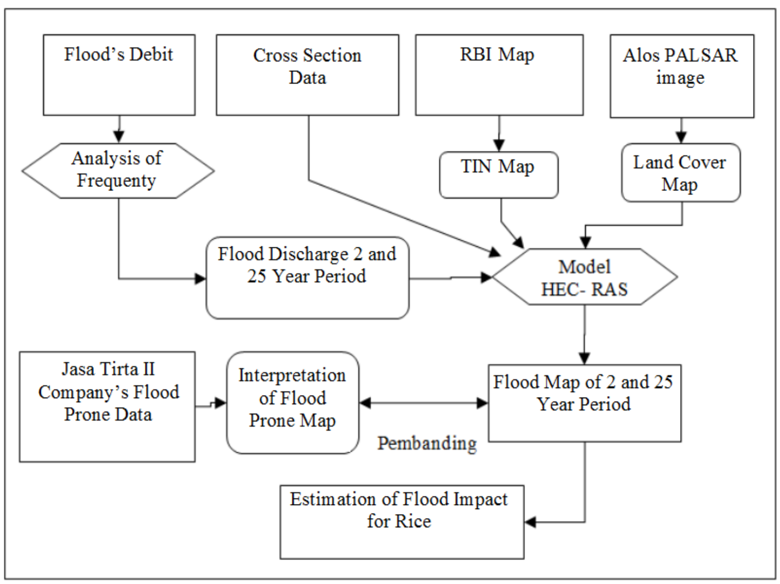

Figure 1: Stage of Analysis

2.4 Methods

2.4.1 Flood Return Period Analysis

Flood Return Period Analysis of Upper Citarum, is determined only on five major tributaries of Citarum River and flood discharge data recorded on three hydrological stations Upstream Citarum (Figure 2).

To study the flood discharge return period was conducted by Gumbell distribution. Flood discharge return period was studied over a period of 2 and 25 years are represented by the following equation:

$$F(x) = \exp\left(-\exp\left[-\frac{x-a}{b}\right]\right) \quad [1]$$

By introducing variables u = [x-a]/b :

$$u = -\ln(-\ln(F(x)) \quad [2]$$

$$F(x) = \frac{r-0.5}{n} \quad [3]$$

where

F (x) = Frequency count

r = rank

n = number of observations

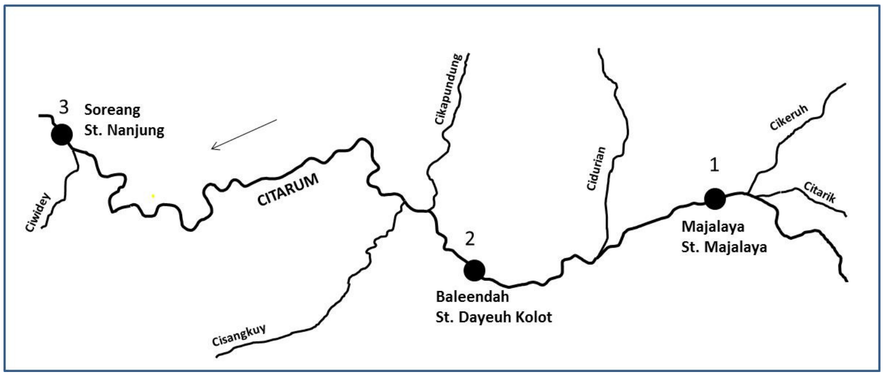

Figure 2: Upper Citarum river basin and major tributaries.

2.4.2 Flood Modelling and Inundation

Flooding and inundation modeling is done based applications Hydrodynamic HEC RAS models that have been developed by the U.S. Army Corp of Engineers (2002) in Bruner (2002), Department of Defense, U.S.. Software ArcGIS and HEC-GeoRAS module is used to generate the data geometric where the results will be exported back into the HEC RAS.

For comparison is done by comparing the results of modeling flood prone map with a map of Flood Prone interpretation of tabular data by Perum Jasa Tirta II were recorded in the period 2000-2008. The end result of this modeling is a map of flood prone areas in the Upper Citarum flood discharge return period of 2 and 25 years.

2.4.3 Calculation of Flood Impact

The impact of flooding is limited to rice alone, which is the main crop in the study area. Understanding the impact of flooding in this study is that rice yield losses caused by flooding, such as crop failure or harvest with results below the average productivity of rice plants in the surrounding area of research. The impact of flooding is calculated in the form of dollars, which is the difference between the average normal productivity multiplied by productivity due to extensive flood flood flood area.

Calculation of the effects of flooding for rice crops refers to the Flood Prone Rice Simulation Model commonly called RENDAMAN.CSM developed by Makarim and Ikhwani (2011). Used as a control in rice production by submerged long zero (0) days, where the conditions of production of rice is considered the same as the potential results are in accordance with the ideal parameters. Makarim research results and Ikhwani (2011) mentions that the rice plants will die if submerged in water for more than 14 days, therefore submerged rice 14 days to the end of the running program. Phase submerged long day will be divided into 5 groups, namely 0 days, 1-3 days, 4-6 days, 7-9 days, 10-12 days and 13-14 days.

Flood losses are calculated in the form of dollars, which is the difference between the average normal productivity multiplied by productivity due to flooding flood extents derived from the interpretation of the flood prone area maps that have been made previously.

3. RESULTS AND DISCUSSION

3.1 Maximum-Minimum Discharge Analysis

Return period flood discharge characteristics required for flood discharge data analysis. Discharge data flow data used is a minimum period of 10 years. Determination of the period of maximum discharge carried by extreme flood events in the history of the Citarum River Basin 1998-2008. Return period flood discharge analysis conducted on five observation posts representing flooding tributary upstream Citarum, while in the main river on three observation posts which represents the area of the river upstream, midstream and downstream areas of research, namely Majalaya upstream, Dayeuh Conservative in the middle and Nanjung downstream. Citarum river flow data used in the analysis of flood discharge was derived from publications issued by the Center for the CRB.

Discharge gap in between the maximum and minimum flow upstream of the Citarum River in three regions observations may indicate that the condition of Citarum has suffered severe damage. Upstream (Majalaya) inequality is the average of the maximum discharge of 41.3 m3/sec and 0.6 m3/sec in for minimum flow. Inequalities become very large in the lower reaches (Nanjung). The average maximum discharge was 349.6 m3/sec while the minimum discharge of 5.6 m3/sec only. If it rains it can bet the upstream Citarum not able to hold the water and running it into the ground, rain falling become into runoff and flows into the river. High amount of rain in a very short time causing flooding in the area of research happens every year.

Table 1: Maximum discharge and minimum discharge of Citarum River in three observation post.

Tahun	Debit (m^3/dt)					
	Majalaya		Dayehkolot		Nanjung	
	Mak	Min	Mak	Min	Mak	Min
1999	18,6	0,9	156,8	2,6	309,9	3,0
2000	40,2	1,6	120,4	19,8	266,0	2,0
2001	25,6	0,9	298,5	21,0	355,3	6,2
2002	30,7	0,5	399,8	3,7	383,2	5,5
2003	19,3	0,6	85,8	5,4	322,1	5,2
2004	67,8	0,0	168,1	5,1	209,7	5,4
2005	59,5	0,0	333,6	5,0	478,6	8,0
2006	34,2	0,5	128,8	2,2	348,0	4,8
2007	56,6	0,3	247,3	0,4	380,9	4,7
2008	60,3	0,6	188,7	0,1	441,9	7,1
Rataan	41,3	0,6	212,8	6,5	349,6	5,2

3.2 Flood Discharge Return Period

Determination of flood return period discharge Citarum River is the next important thing after analyzing the gap between the maximum-minimum discharge. This analysis is used as a method for estimating extreme values such as the distribution of the maximum discharge value opportunities observed during a certain period. The maximum discharge value of the return period is used to analyze the extent to which the distribution, extent and depth of flooding that occurred at the time of discharge values Citarum rivers approaching flood return period discharge value.

Daily discharge data used for the analysis of the flood is the maximum daily discharge that ever happened in a year for a minimum period of 10 years which was then analyzed using frequency analysis by Gumbel method.

For purposes of analysis of the flood in the Upper Citarum, the determination of flood return period discharge data covering five major tributaries that enter the Citarum River and flood discharge data at three observation posts Citarum river flooding upstream. In HEC-RAS, flood return period discharge data is a key data needs to be inputted into the system to perform analysis of flow simulation can be permanent (Steady Flow Analysis). Along the river geometry parameters include slope, cross-sectional shape of the river as well as the shape of the land surface kekasapan flood simulation distribution that includes the distribution, extent, flood depth and flow velocity can be determined at each reset period.

Daily discharge data used for the analysis of the flood is the maximum daily discharge that ever happened in a year for a minimum period of 10 years which was then analyzed using frequency analysis by Gumbel method. Return period flood flow data for 10 stations observed flood are shown in Table 2.

Tabel 2 : Discharge of flood return period of Citarum River and its tributaries through Gumbell analysis

No	River	Flood dischrge of return period (m3/s)					
		2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
1	Citarik	10	28	39	53	64	74
2	Cikeruh	7	11	14	17	19	21
3	Ciwidey	19	44	60	81	96	111
4	Citarum	185	281	345	425	484	543
5	Cikapundung	12	17	20	24	28	31
6	Cisangkuy	59	85	102	123	139	155
7	Citarum Pos Majalaya	39	55	66	79	89	99
8	Cikapundung	11	18	22	27	31	35
9	Citarum Pos Nanjung	292	360	405	462	505	547
10	Cidurian	4	8	11	14	17	19

Source: BBWS Citarum

3.3 Flood Prone Areas

To determine the Citarum River flood-prone areas required data and maps with a scale sufficient detail. The main data in flood modeling with HEC-RAS modeling is data altitude (elevation) and the land use map. Elevation data used to determine the position and into a puddle, while the land use data used to determine the shape of the land surface kekasapan effect on the friction and velocity of water flow. In Table 3 are shown Manning Value of Surface and land use in the area of the study site.

Table 3: Manning Value and surface area of land use in the study site.

LandUse	Manning Value	Luas
Water body	0,07	194,25
forest	0,15	185,98
Industrial / Office	0,013	261,97
garden	0,03	1.849,97
settlement	0,013	6.915,24
Grass / courtyard	0,07	1.130,29
Irrigation Rice Field	0,04	15.788,10
Rainfed rice fields	0,04	109,35
bush	0,07	183,70
Rocky soil	0,035	5,86
Moor / Field	0,03	2.616,61
Total		29.241,32

The construction of the river is the most important factor in flood mapping, therefore river flow boundary determination (wet weight), river banks and flood flow path must be defined carefully. In this study the determination of the boundary flow, river banks and river flowpath created using satellite imagery ALOS AVNIR 2010. Withdrawal transverse river intended to reconstruct the shape of the cross section of the river at any given distance. The more tightly withdrawal transverse distance will give better results, because it can illustrate the true hue approaching the river. The end result of the process of withdrawal of transverse lines are 3-dimensional shape of the river profiles generated with overlay way between the transverse shape of the earth's surface with a stream of the Citarum river basin TIN map.

HEC-RAS simulation results in regions Nanjung shows that at each point of the surface water discharge return period flood riverbank above the limit, even exceeding the river embankment is located at an altitude of 666.5 to 668.2 meters above sea level, or about 1.7 meters above sea level is higher than the limit riverbank .

Extrapolation of the results of the HEC-RAS simulation on using GEO HEC-RAS simulations show that the flood-prone area on the flood return period discharge 2 year amounted to 2155.85 ha, while for discharge flood return period of 25 years is 2535.06 ha) as shown in Table 4. map flood-prone areas on the flood return period discharge 2 and 25 years are presented in Figure 4 and 5.

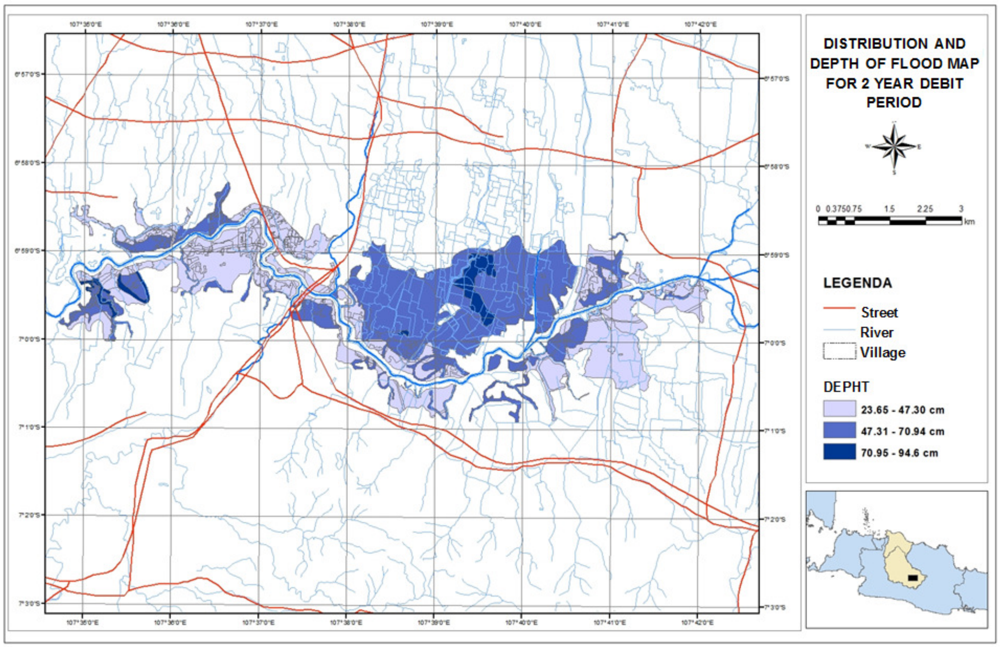

Figure 3: Distribution and depth of flooding Map for 2 years period flood discharge.

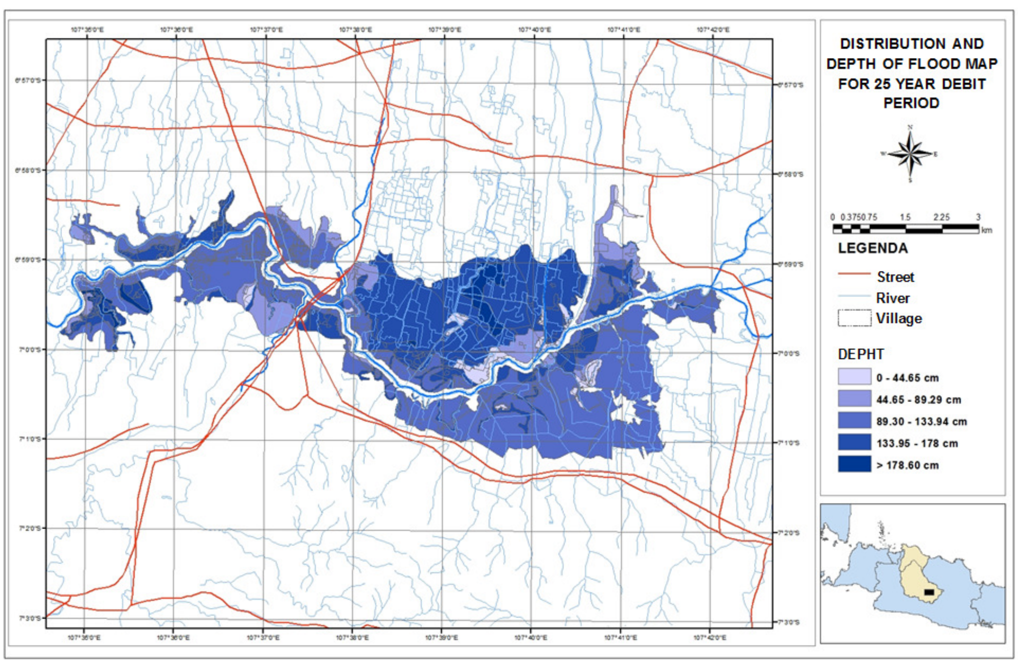

Figure 4: Distribution and depth of flooding Map for 25 years period flood discharge.

3.4 Comparison of Flood Prone Map

Figure 6 looks at the distribution pattern similarity flood-prone area of the flood prone map of HEC-RAS modeling to map flood-prone interpretation of the data recording area of flooding is done by Perum Jasa Tirta II from 2000-2008.

Distribution of flood-prone areas on the second map coordinates collected at 107.35 to 107.42 and 6.58 to 7.1 OLS OBT. Small differences occur only in zone 1 and zone 3, while the greatest similarity are in zone 2, which is largely a wetland. The cause of the difference was estimated as topographic contour map of the study area is too wide but nevertheless it appears that the HEC-RAS model suitable for use in preparing a map of flood-prone rice field, so expect major flood losses in rice plants can be done through this modeling.

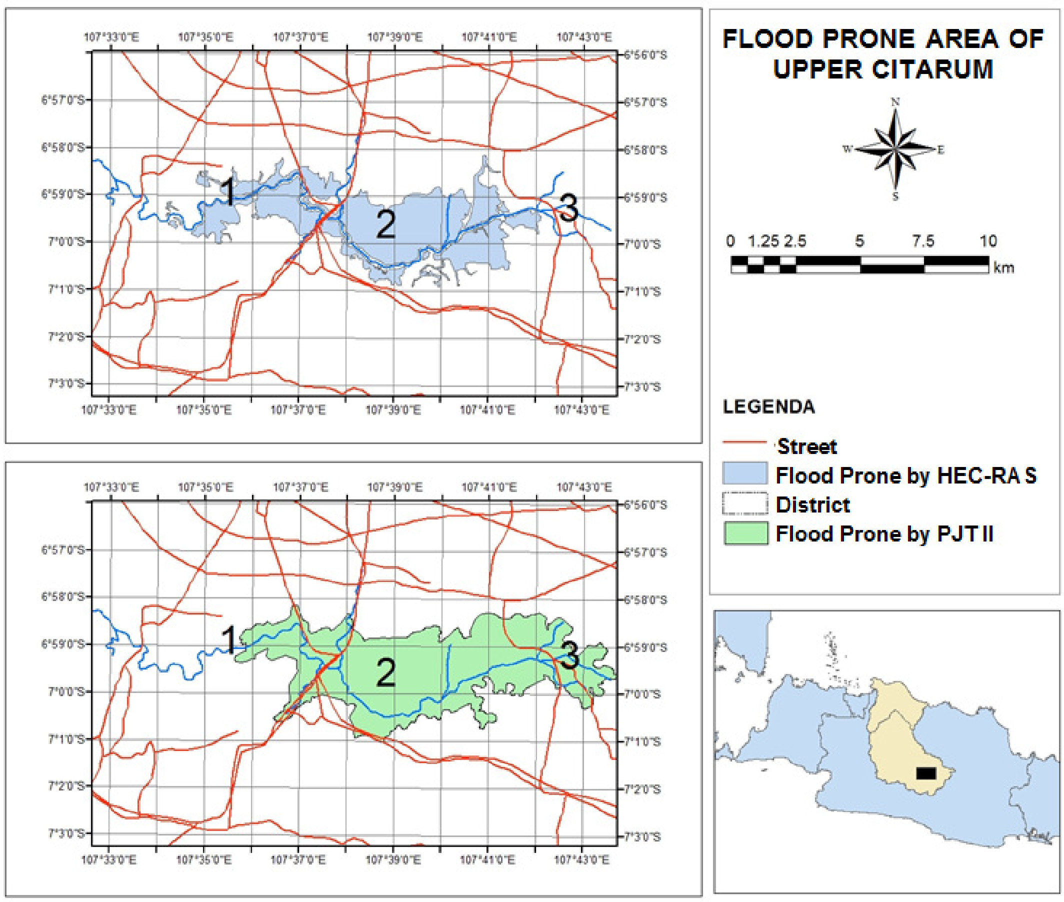

Figure 5 Comparison of flood-prone areas by HEC-RAS modeling and observations result.

3.5 Calculation of Flood Impact

In this study I set the rice planting season beginning in January (existing planting time), while the incidence of extreme discharge at the sites usually occurs in mid-January to mid-February). At the time of the flood events can be ascertained that the age is at vegetative phase of rice. Simulation of existing rice yield reduction (Ciherang) in the vegetative phase in the research area using RENDAMAN.CSM the model shown in Figure 7.

The simulation results in Figure 8 shows that the production of local rice varieties (Ciherang) dropped dramatically when stagnant between 1 and 9 days on vegetative pase. Value of rice production decreased from the normal production of about 6.8 tonnes per hectare to 3.7 tons per hectare on day 6 and 1.5 tons per hectare on day 9, and then ramp approaching death that is characterized by the production of near-zero . So it can be ensured that all the flooded rice plants for 15 days at the age of 14-24 HST planting will die so that production becomes zero.

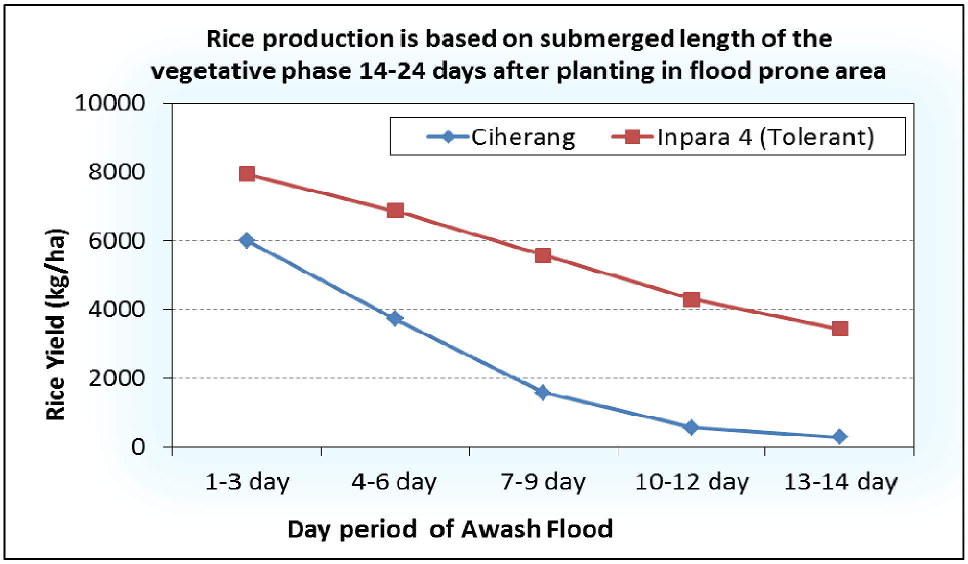

Figure 6 : Alleged decline in rice yields of existing varieties and varieties resistant based on the length of the day soaking in the flooded areas of research using simulation models RENDAMAN.CSM.

The simulation results are very similar to the research conducted Ikhwani and Makarim (2012) which gives the rice planting immersion treatment using water for 1 to 15 days. They mentioned that the rice plants submerged in vase primordia suggests that flood-tolerant varieties are not damaged and die 100% whereas for flood tolerant varieties will recover (recovery) 100% and grew normally until harvest. However, the results were varied depending on varieties. Furthermore Ikhwani and Makarim (2012) mentions the condition of the old flood water with turbidity levels are high enough to the limited diffusion of gases in water, inhibition of sunlight and thus reduce the efficiency of photosynthesis and carbohydrate utilization. Thus, the power plant life in the bath depends on the amount of carbohydrate supply before submerged plants and the capacity to sustain energy production through rapid alcoholic fermentation in oxygen-less conditions.

The process of extrapolating from this RENDAMAN.CSM results obtained through GIS analysis of total loss of rice due to floods in the Upper Citarum River flood discharge 2nd annual incidence of approximately 8.54 billion rupiah (USD $ 718,000) covers 7 districts with a total land area of the flooded rice fields reached 1628.22 ha (Table 3). Rice losses increased 3-fold to 25.85 billion rupiah (USD $ 2 milion) floods that hit occurs when the return period flood discharge 25 years. Increased flooding occurs mostly due to longer submerged paddy approximately 7 to 8 days where rice production decreased by 71 per cent of normal production that occurs in 8 districts with a total area of rice fields affected by flooding approximately 1886.11 ha.

Further analysis of the effect of water level upstream of the Citarum River flood losses rice per hectare is showed in Table 4. Data high influence on long stagnant floodwaters actual data obtained from Upper Citarum River flood period 2000-2008 were analyzed by the use of the regression equation, while decreasing rice production is obtained from the simulation results RENDAMAN.CSM. Flood losses to rice will be seen occur if high floodwaters are at an interval of 50-65 cm. Long inundation occurred was 5 days with a reduced rate of approximately 45.85 per cent of rice, equivalent to 8.8 million dollars.

This condition certainly will always occur every year due to the period of the flood event always coincides with the period of the first planting rice planting notabenenya is that always gives the highest production compared to the second and third growing season. Sometimes in the field often encountered farmers who harvest their crops even though grain was still half full. Grain is harvested in this manner, when the ground can produce rice groats. Straw submerged by floods can not be used as animal feed, due to rot and cattle do not like that.

Tabel 4: Simulation of the effects of flooding on the Upper Citarum rice crop losses in the event of a 2 years flood period.

Sub District	Broad fields were flooded (ha)	Normal production (kg)	Simulation results RENDAMAN.CSM Rice Production (kg)	Value Losses (USD)
2 YEARS PERIODE FLOOD DEBIT				
Baleendah	330.17	2,268.29	1,869.26	93,890
Bojongsoang	996.70	6,847.33	4,367.87	583,402
Ciparay	168.99	1,160.99	1,083.22	18,300
Dayeuhkolot	71.40	490.51	437.94	12,372
Ketapang	31.82	218.59	180.10	9,058
Majalaya	4.28	29.44	29.44	
Margahayu	24.85	170.73	166.58	977
Jumlah	1,628,22	11,185,88	8,134,39	717,999
25 YEARS PERIODE FLOOD DEBIT				
Baleendah	404.38	2,778.07	804.10	464,463
Bojongsoang	1,122.65	7,712.59	2,072.41	1,327,102
Ciparay	179.31	1,231.87	331.12	211,941
Dayeuhkolot	99.05	680.45	299.82	89,558
Ketapang	37.24	255.81	87.17	39,680
Majalaya	4.28	29.44	6.73	5,343
Margahayu	33.93	233.08	97.37	31,931
Rancasari	5.28	36.25	25.95	2,421
Total	1,886.11	12,957.54	3,724.67	2,172,440

IDR 11,900 = USD $1

Table 5: Influence of water level on the duration of inundation and loss of rice per hectare in the upper Citarum river flood events.

No.	Flood Inundation Height (cm)	Puddle long (days)	Decrease in Rice Production (%)	The loss value per hectare of paddy rice (USD)
1.	10 - 50	1-4	0.00	0
2.	50 - 85	5-6	45.85	588.24 - 741.18
3.	85 - 175	7-9	77.15	741.18 - 1,247.06
4.	175 - 310	10-13	91.70	1,247.06 - 1,482.35

IDR 11,900 = USD $1
Description: 1 kg of dry grain harvest price = USD $ 0.24 and normal production = 6,800 kg/ha ~ USD $ 1600

To avoid damaging results that are too high can be cultivated with the introduction of flood-tolerant rice varieties, or can also be done by planting date change to avoid flood events. Flood-tolerant rice varieties are the most best Swarna sub-1 (Inpara 4) because it produced the highest grain and have better endurance (Ikhwani and Makarim, 2012). The introduction of these varieties is expected to reduce the impact of flood losses significantly. Some other ways: (1) Making management priorities based on aspects of climatology, hydrology, and agronomic easy and relatively cheap, especially in areas with the highest impact of flooding and rice fields or in areas where the drainage network / irrigation suffered heavily damaged, and agronomically This region is the center of rice production mainstay. (2) Establish a systematic way of handling steps, namely (a) the general strategy: each of the districts to date and more detailed planting patterns by taking into account the climate forecast, the adequacy of the water discharge. The cropping pattern is evaluated every 2 weeks; (B) the specific strategies: each flood region, tani/P3A group along with officers of the local agriculture and Irrigation Department should conduct a careful examination in each work area before planting, covering channel readiness in supporting the implementation of the planting pattern; build a network of farm-level and micro-water system or network at each location to improve the efficiency of water availability; (C) introduction of plant / crop varieties that are resistant immersion, while waiting for the repair and improvement of the watershed upstream flood prevention infrastructure.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

1) HEC-RAS model is able to simulate the flood discharge in the Upper Citarum well especially in paddy fields.
2) Based on the analysis of HEC-RAS, DAS Citurum Hulu highly susceptible to flooding, it is shown from the simulation results of two annual flood affected areas reached 2155.85 ha.
3) Impact of rice crop losses due to floods with a return period of 25 annual discharge is three times higher than the losses of rice due to floods over 2 year period.

4.2 Suggestion

1) Need further research and development using a more tightly contour map, especially on a scale of 1:5,000 over that map flood-prone areas to be very detailed and more accurate.
2) Need further research and development in order to integrate all the models that are used into a more comprehensive model.

5. REFERENCES

Aini, A. 2007 Sistem Informasi Geografis, Pengertian dan Aplikasinya. *Journal Ilmiah DASI (Data Manajemen Dan Teknologi Informasi)* vol. 8. No. 2. Juni 2007 ISSN:1411- 3201 p. 23

Bates, P.D., Horritt, M.S., and Fewtrell, T.J. 2010. A Simple Inertial Formulation of The Shallow Water Two-Dimensional Flood Inundation Modeling. *Journal of Hydrology* 387 (2010), 33–45.

Bruner, G.W. 2002. “HEC-RAS, River Analysis System User’s Manual”. US Army Corps of Engineers: Hydrologic Engineering Center (HEC),

Chen, J., Hill, A.A. and Urbano, L.D. 2009. A GIS-Based Model For Urban Flood Inundation. *Journal of Hydrology* 373 (2009), 184–192.

Cook. A., and Merwade, V. 2009. Effect of Topographic Data, Geometric Configuration And Modeling Approach on Flood Inundation Mapping. *Journal of Hydrology* 377 (2009), 131–142.

Era Baru News, 2010. Dua Kampung Hulu Sungai Citarum Dilanda Banjir. [http://erabaru.net/nasional/50-jakarta/10259-dua-kampung-hulu-sungai-citarum-dilanda-banjir].[3 Juni 2011].

Fongers, D. 2002. A Hydrologic Study of the Ryerson Creek Watershed, Hydrologic Studies Unit, Land and Water Management Division Michigan Department of Environmental Quality.

Ikhwani dan A.K Makarim. 2011. Respon Varietas Padi terhadap Perendaman, Pemupukan dan Jarak Tanam. *Journal Penelitian Pertanian* No. 30(2):1-9 Pusat Penelitian dan Pengembangan Tanaman Pangan. Badan Litbang Pertanian

Kadri, T. 2007. Penerapan Sistem Informasi Geografis Dalam Untuk Mereduksi Kerugian Akibat Banjir. Prosiding Seminar Nasional Aplikasi Teknologi Informasi 2007 (SNATI 2007) ISSN: 1907-5022. Jogjakarta

Koutroulis, A.G and Tsanis, I.K. 2010. A Method For Estimating Flash Flood Peak Discharge In a Poorly Gauged Basin: Case study for the 13–14 January 1994 flood, Giofiros basin, Crete, Greece. *Journal of Hydrology* 385 (2010), 150–164.

Lerat , J., Perrin, C., Andréassian, V, Loumagne, C., and Ribstein, P. 2009. Towards Robust Methods to Couple Lumped Rainfall–Runoff Models And Hydraulic Models: A Sensitivity Analysis on The Illinois River. *Journal of Hydrology* 377 (2009), 131–142.

Makarim, A.K. dan Ikhwani. 2011. Inovasi dan strategi penanggulangan banjir terhadap Usahatani padi. Jurnal Tanah dan Lingkungan IPB.

Perrin, C., Michel, C., Andréassian, V. (2003). Improvement of a parsimonious model for streamflow simulation. Journal of Hydrology 279(1-4), 275-289.

Pistocchi, A. and Mazzoli, P. 2001. Use of HEC-RAS and HEC-HMS model with ArcView for Hydrologic Risk Management.

Prahasta, E. 2001. Konsep-Konsep Dasar Sistem Informasi Geografis. Bandung : Informatika.

Rajab, B. 2010. Banjir di Cekungan Bandung. Harian Kompas. http://cetak.kompas.com/read/2010/03/19/15455191/banjir.di.cekungan.bandung. [11 April 2011]

Reynolds, H. 1997. An Introduction To Geographical Information Systems (GIS). http://www.badpets.net/IntroGIS/GIS_Intro.pdf. [23 Mei 2011]

Sugiura T. , Fukami K. , Fujiwara N. , Hamaguchi K. , Hironaka S. , Inomata H. , Ishikawa M. , Itou K. , Nakamura Ka. , Nakamura Sh. , Shimizu T. , Wada T. 2009. Development Of Integrated Flood Analysis System (IFAS) And Its Applications. Public Works Research Institute (PWRI). Japan.

Sanders, S., and Tabuchis, S. 2000. Decision Support System for Flood Risk Analysis for the River Thames, United Kingdom. *Photogrammetric Engineering & Remote Sensing* Vol. 66 No. 10. United Kingdom.

Windarta, J. 2009. Pengembangan Sistem Peringatan Dini Banjir Kaligarang Semarang dengan Teknologi Informasi Berbasis SMS dan Web. Disertasi. IPB. Bogor. 162 Hal.