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Volume 24 - Issue 5

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### The Influence of Land Use Change toward Hydrological Aspect at Upper Site

👤 Firman Hidayat

#### Abstract

The Impact of land-use change not only give some benefit to community but also can cause problem, namely: erosion, sedimentation, flooding and other. Erosion will cause silting of reservoirs, reducing irrigation channel capacity, and disrupt electrical power generation systems. High erosion, flooding in the rainy season not only have a negative impact on the biophysical aspects of natural resources and the



## "The influence of Land Use Change toward Hydrological Aspect at Upper Site " Mahat Watershed

**Dr.Ir.Firman Hidayat,MT**

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### **Abstract**

The Impact of land-use change not only give some benefit to community but also can cause problem, namely: erosion, sedimentation, flooding and other. Related with that case the research will be taken. The objective is, to analisis influence of land use change to hidrological aspects. at Mahat Hulu watershed, located in the Lima Puluh kota district that 15 years old (1995-2010) deforestation has taken significantly. In 1995 Watershed has Forest area approximarely 50.9% and in 2010 decrease into 28% or from 14523 ha (1995) decrease to 7981 ha (2010) but mix garden increased from 17.1% (1995) to 43.8% (2010) or 4889 ha (1995) to 12508 ha (2010), the influence of land use changes on the hydrological aspects such as coefficient of annual and seasonal runoff, and fluctuations. The method used quantitative and multiple regression test. Result of analysis are deforestation will increases coefficient run off, and fluctuations discharged. Coefficient runoff from 20% in the 1999-2002 to 24% in 2007-2010 and fluctuation of discharged (KRS) also increased from 2.4-5.5 (1999-2002) to 5.9-10.7 (2007-2010) indicating DAS is critics. Results of multiple regression test showed a close correlation between the variables (0.9) the formula is  $C(\%) = 975 - 11.2 \text{ htn} - 15.3 \text{ kbn cpr} - 10.9 \text{ smk blkr} + 0.43 \text{ tgln}$  dan  $R\text{-Sq} = 42.4\%$ , for the stepwise regression test showed that forest area influence to run off. It can be showed from the equation is  $CRO = 31.5 - 0.370 \text{ htn}$ , ,  $R\text{-Sq} = 5.3\%$ .

**Keywords** *Hydrology, erosion, sedimentation, runoff, fluctuations*

### **Introduction**

The research was conducted in the watershed upstream Mahat (28535.49 ha) which has been degraded due to conversion of forest lands into new agricultural areas and illegal logging. Erosion level on site and off site sedimentation level is due to the opening of the land surface. This was reported by Berd I. (2003) due to a reduction of 50.89% forest in 1995 to 40.24% in 2003 the erosion has reached 172.92 tonnes / ha / yr which affect the volume of the reservoir once the turbine installed capacity

Excessive volume of runoff that could potentially cause flooding downstream. This is in accordance with the opinion Irianto (2003) which states that the annual rainfall accumulated in a short period (December-February) cause the land is not able to accommodate all of the volume of rainwater. Consequently most of the rain water runoff, it is exacerbated by the increasing conversion of forests to other uses such as agricultural, residential, and industrial fields. That will cause considerable potential flooding in downstream areas. Further it is said that the amount of surface

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*Manuscript submitted: ... , Manuscript revised: ... , Accepted for publication: ...*

runoff will also cause excessive erosion, so it will directly reduce soil fertility. Decline in soil fertility will cause the less vegetation is able to grow properly, so the diminishing forest cover. This will cause a reduction in charging (*recharging*) upstream water reserves which cause a drought during the dry season.

Meanwhile, according to Arsyad (2010) surface flow (*run-off*) is water that flows over the ground surface. This runoff can cause soil erosion, being able to carry part of the land in dispersed by raindrops. In this sense the flow of run off is above ground level before they reach the water in the canal or river. Factors influencing of run off properties are as follows; rainfall; (amount, rate, and distribution), temperature, soil: type, substratum, topography, broad basins, vegetation for cover crop (type, number, and density), and land cultivation system. Controlling of runoff will have impact directly to erosion, which in turn will affect the availability of water in the dry season and the rainy season flood prevention.

Converting area from forest into agricultural land recognized cause many problems such as decreased soil fertility, erosion, extinction of flora and fauna, floods, droughts and even global environmental change. This problem will increase during forest are converted to other business future. (Banuwa, 2008) reported a relation between erosion and deforestation, namely the erosion of a *small catchment areas* in French Guyana French, increased dramatically after deforestation (*deforestation*). Observations were conducted on small-scale plots also showed that the logging of natural vegetation has led to an increase in *run-off* coefficient of 25-100 times, while the erosion increased as well to more than 10 times (Roose, 1986). Opened area causes fluctuations in temperature and soil moisture regime becomes larger. This leads to accelerated decline in soil organic matter (Lal, 1994). Run off is part of precipitation that flows on the surface and subsurface level and next reach to lower area such as: lake or sea (Schwab *et al.*, 1981). For that reason this research was conducted. The objective is analysis of land use change to hydrological aspects at DAS Mahat Hulu watershed at Lima Pulub Kota District.

## Method

The tools and materials used in this study consisted of *Geographical Position System (GPS)*, cameras, computer hardware PC / Laptop Toshiba Window Xp, software, microsoft word 2007, microsoft excel, program ArcView version 3.2, and ARC GIS. and Minitab 14. Materials used such as: Data discharge, RBI maps, climate maps, maps land use, soil maps, geology maps, *Landsat ETM7* 1995, 2000, 2005 and 2010,

### Types, Sources and Uses of Data

Secondary data, including data physic required in this study includes the data types of land use, topographic data, soil data, discharged data, and climate data. climate data (rainfall) obtained from a Sicincin BMKG station daily data from the year 1995 to 2010. While the discharge data obtained from hydropower Koto Panjang and BWS II Inderagiri Hulu, a monthly discharge data in 1999 - 2010 and the daily discharge in 2004 - 2010 (Table 1)

Table 1 Types, sources and uses of data

| No. | Data Type   | Sources of Data   | Usefulness of Data  |
|-----|---|---|---|
| A.  | Secondary Data                                    |   |   |
| 1.  | Map-Map<br>ETM7 Landsat imagery (30 m resolution) | BP DAS Indragiri Rokan (1995, 2000, 2005, and 2010), Riau Provincial Forestry Office, | To arrange land units, which would then be used in the estimation of runoff and |

|    |   |   |   |
|----|---|---|---|
|    | Land use maps (scale<br>Topographic maps<br>Map of soil types<br>Forest boundary map<br>Geological map<br>(Bf Scale: 1: 50,000) | Bakosurtanal, Land Research<br>Centre, Directorate of Land Use, | erosion   |
| 2. | Mahat watershed upstream discharge data   | Hydroelectric Koto Panjang<br>SWS II Inderagiri                 | To see the change in flow<br>rate upstream sub-watershed<br>Mahat due to changes in<br>land use |
| 3. | Climate data (rainfall)   | BMKG Sicincin   |   |

### Data Collection Techniques.

At this stage, identification, inventory, and procurement of materials and the necessary data, such as contour maps, map earth way, the image of *Landsat 7 ETM* man pereka year 1995, 2000, 2005, and 2010, soil map scale 1:50. 000, Map slopes *digital elevation* maps obtained through *the model* (DEM) scale 1: 50. 000 is processed through contour map scale of 1: 50. 000 with using the program *ArcView 3.2*.

**Land use.** Land use data obtained from image analysis of *Landsat ETM 7*, k emudian conducted *ground check* / observation at sample sites in the field to see the development of existing land-use change. Data land use is analyzed land use data are available the last 15 years (1995, 2000, 2005 and 2010)

**Rainfall.** Rainfall data is daily data, the data is collected from the Meteorology, Climatology and Geophysics Agency (BMKG) Sicincin, starting in 1995 through 2010

**Mahat discharge upstream.** Water discharged collected is monthly data for 12 years (1999-2010), and daily data from 2004 to 2010, this data is used to see the continuing effect of land use change on hydrological factors.

### Method

*Landsat* images were analyzed using *ERDAS V, 8.7* For getting land use information contained in the image is done *klasifikasi* the *Landsat* image *ETM* recording 7 years 1990,1995,2000 and 2010. Classification method used is the maximum similarity classification supervised (*maximum likelihood supervised classification*), where each spectral class is described by a probability distribution in a *multispectral* space. *Overlay* analysis techniques using *ArcView 3.2* aims to determine the type of the existing spatial changes between 1995 to 2010

To see the effects of changes in land use or watershed response Mahat Hulu to hydrology aspects that is input into the discharge rain, it will be the analysis of rainfall, flow analysis and land-use change. Discharge data analysis will be done by looking at the trend of the influence of land use change on river discharge is generated. The method used is the mathematical models namely multiple regression analysis (*multiple regression*) to illustrate the degree of correlation between several independent variables and the dependent variable, discharge data is the data that will be used monthly discharge series Mahat Hulu DAS 12 years (1999-2010)

Regression mathematical form as follows:

$$Q_{\max} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_n x_n + \epsilon$$

$$Q_{\min} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_n x_n + \epsilon$$

$$CRO = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_n x_n + \epsilon$$



where  $x_1, x_2, x_3, x_4, x_5,$  and  $x_n,$  was the proportion of each type of land use,  $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5$  and  $\beta_n$  coefficients regression of each variable  $x$ , while  $\epsilon$  is the residual or error is assumed to be normally distributed with mean 0 and standard deviation close to certain.

**Discussion**

**Land use change at Mahat Hulu watershed**

Analysis of land use changes of the image is done in three (3) periods of time ie 1999-2002, 2003-2006, and 2007-2010 for more details can be seen in the following table (Table 2)

Table 2 Changes in land use in the watershed upstream Mahat 1995-2010

|   |              | Periode<br>1999-2002 |              | Periode<br>2003-2006 |              | changes<br>Ha (%) |              | Periode<br>2007-<br>2010 |              | changes<br>Ha (%) |              |
|---|--------------|----------------------|--------------|----------------------|--------------|-------------------|--------------|--------------------------|--------------|-------------------|--------------|
| 1 | Forest       | 11,200.2             | 39.3         | 9,683.8              | 33.9         | (1,516.4)         | (5.3)        | 8,447.6                  | 29.6         | (2,752.6)         | (9.6)        |
| 2 | Mix garden   | 8,443.3              | 29.6         | 10,408.0             | 36.5         | 1,964.6           | 6.9          | 11,976.0                 | 42.0         | 3,532.7           | 12.4         |
| 3 | shrubs       | 3,164.2              | 11.1         | 2,911.8              | 10.2         | (252.4)           | (0.9)        | 2,720.0                  | 9.5          | (444.2)           | (1.6)        |
| 4 | Dry lands    | 2,447.3              | 8.6          | 2,251.4              | 7.9          | (195.9)           | (0.7)        | 2,111.3                  | 7.4          | (335.9)           | (1.2)        |
| 5 | Wet lands    | 1,800.2              | 6.3          | 1,897.7              | 6.7          | 97.4              | 0.3          | 1,908.0                  | 6.7          | 107.8             | 0.4          |
| 6 | Settlement   | 65.1                 | 0.2          | 68.4                 | 0.2          | 3.3               | 0.0          | 69.7                     | 0.2          | 4.6               | 0.0          |
| 7 | Water        | 217.7                | 0.8          | 283.7                | 1.0          | 66.0              | 0.2          | 306.5                    | 1.1          | 88.8              | 0.3          |
| 8 | cloud        | 1,197.4              | 4.2          | 1,030.8              | 3.6          | (166.7)           | (0.6)        | 996.3                    | 3.5          | (201.2)           | (0.7)        |
|   | <b>Total</b> | <b>28,535.5</b>      | <b>100.0</b> | <b>28,535.5</b>      | <b>100.0</b> | <b>(0.0)</b>      | <b>(0.0)</b> | <b>28,535.5</b>          | <b>100.0</b> | <b>(0.0)</b>      | <b>(0.0)</b> |

Source: Results of Landsat imagery interpretation ETM7 (1995-2010)

Table 2 is seen that watershed land use Hulu Mahat period 1999-2002 consists of 6 (six) in addition to the use of water bodies and cloud are: a) forest, b) mixed garden, c) shrubs, d) dry land, e) wet land, and f) settlement. In this period DAS Mahat Hulu is still dominated by forest vegetation covering an area of 11200.2 ha (39.3%), and mixed garden 8443.3 ha (29.6%), while at the end of the period 2007-2010 forest area only 8447.6 ha (29.6%) decreased 9.6% (2752.6 ha), but 11976 ha of mixed gardens, increased 12.4% (3532.7 ha). For more visibility upstream Mahat watershed land use can be seen from Figure 1 map land use Hulu Mahat DAS 1995.and 2010. Deforestation cause by new agricultural land, especially for gambir.

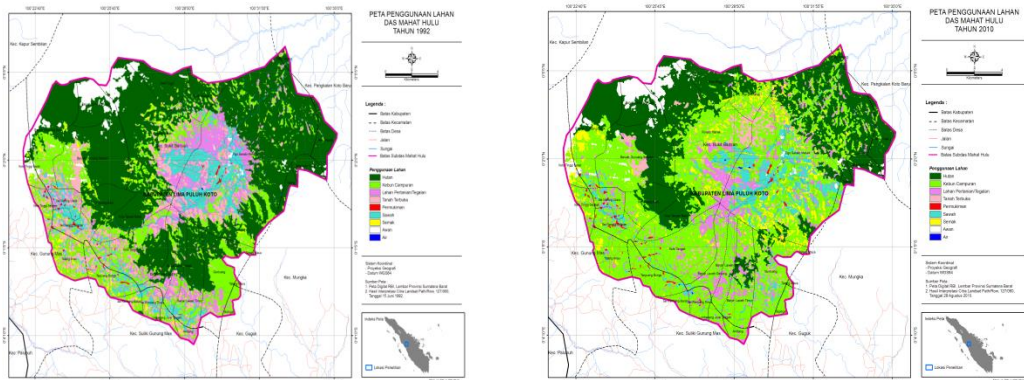


Figure 1 Land use map Mahat Hulu Watershed 1995 and 2010

## Subsection 1

### Rainfall and discharge at Mahat Hulu watershed

Based on rainfall data for 15 (fifteen) years period 1995-2010, the magnitude of the average annual rainfall Mahat Hulu watershed is 1978 mm / year. Wet season generally occurs from the months of October to April, while in dry months from May to September. The highest monthly average rainfall occurred by 16 days in October and the lowest occurred in May 8th day of rain (Figure 2)

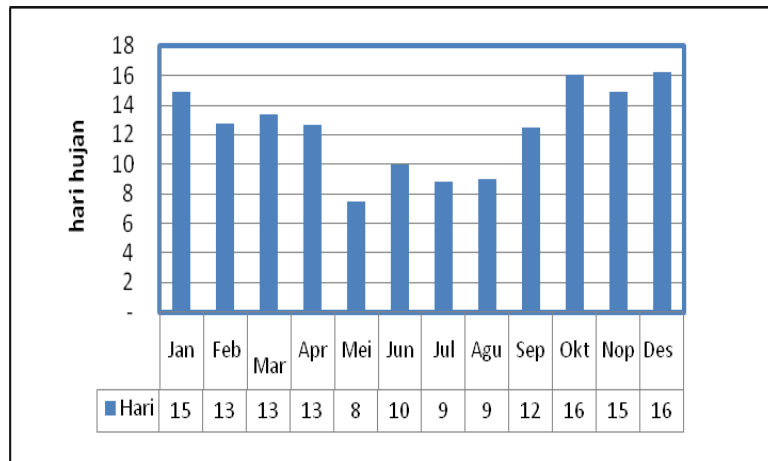


Figure 2 day average monthly rainfall Mahat Hulu watershed (1995-2010)

Rainfall is the highest monthly average (259 mm) occurred in February and the lowest (71 mm) fell in July. Such rain patterns greatly affect the volume and distribution of river discharge. In wet season rainfall is very high and the otherwise very dry in dry season

### The influence of land use change to hidrological aspects

Relatively high rainfall in the wet months are potentially increase runoff. This situation is also supported by a dwindling forests throughout the watershed Mahat Hulu. Changes in the use of forests to other land uses, causing the surface of the land to be open, with moderate clay content and low to moderate infiltration capacity. rain water more then at ground level or increased runoff. Similar with the statement Baver (1956) divides the influence of vegetation on surface flow and erosion into five parts, namely 1) Role in the interception, 2) Reducing speed and destructive power flow surface, 3) The influence of the root, 4) Biological aspects, and 5) Transpiration. While Arsyad (2010) says that the surface flow is strongly influenced by rainfall (amount, intensity and distribution), temperature, soil (type, type, layer of soil, and topography), watershed area, vegetation cover and soil management. However, because each factor has contributed a very complex one another, the estimation of runoff that is really close to the real situation is still relatively difficult.

Furthermore the average daily discharged for the period (1999 -2010) ranged from 11.19 to 15.07 m<sup>3</sup>/sec Distribution pattern of the average daily discharge generally follow the pattern of rainfall in the Mahat Hulu watershed. Relationship between the magnitude of the average monthly rainfall with an average monthly streamflow upstream Mahat Hulu watershed shown in Figure 3 which shows the results of water (*water yield*) in the form of volume and distribution of discharge that occurs in addition affected by the main input (rain), also influenced by the biophysical conditions DAS is concerned as the condition of land cover, soil type, and topography. Which states the existence of forests in controlling surface and the discharge is not infinite, but there are factors outside the forest that is the amount of rainfall, slope, geology (soil) and land use. If one of the

factors that are experiencing changes in the hydrological conditions in question would change include surface runoff and river discharge (Pudjiharta, 2008).

Increased runoff curve also indicates an increase of the amount of rain that turned directly into the discharge. As a result the higher discharge during the wet season (October to April) and lower in the dry season (May to September) Suryani.E and F. Agus (2005) reported that in the period 1992-2002 in Cilajupang watershed (2792 ha) has been done deforestation by 2, 35% and approximately 7.27% mix garden, but at dry land increased by 5.64% and the settlements around 5, 11%. The impact of land-use change that occurred was an increase in total annual water yield though not significant (+0.35%). Significant changes occur in the flow components. Total runoff increased by 12.37% and the basic flow decreased by 2:54%.

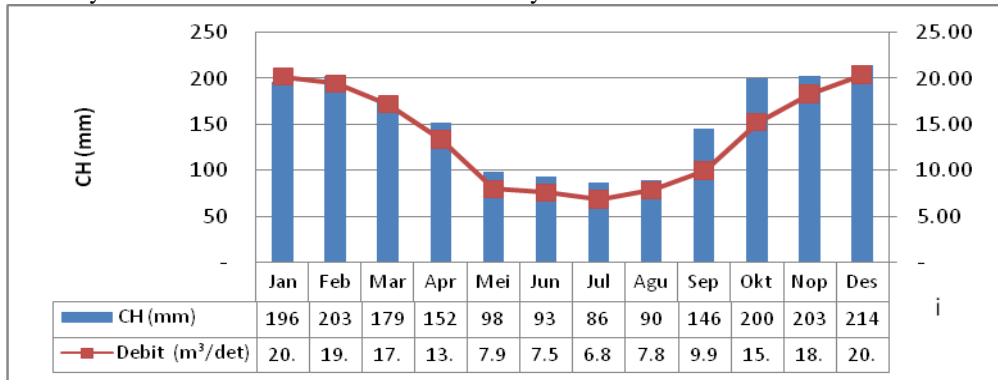


Figure 3 The relationship between monthly rainfall 1999-2010 (mm) with an average daily discharge Mahat Hulu watershed 1999-2010 (m<sup>3</sup> / sec)

Land use changed has increased annual runoff coefficient (C) than the average 20% to 24% (Table 3). The amount of surface runoff coefficient that describes the loss of water can not be used, because the direct flow and thrown away without being able to be used. Such a large loss of water caused by changes in the use of forest land to other land uses, especially for mixed gardens, which are supposed to reduce infiltration capacity so that the amount of rain water into the surface flow is much greater than that infiltrated. To it is necessary forest rehabilitation and the application of agrotechnology to reduce runoff and increase infiltration at Mahat Hulu watershed. Like what is proposed by Suwardjo (1981) that the use of one application of mulch Agrotechnology very effectivet to reduce runoff and soil erosion, its effectiveness depends on the amount and durability of the decomposition process, one kind of straw mulch is effective enough on land with slopes up to 26 percent.

Table 3 Runoff coefficient (C) DAS Mahat Hulu 4th annual periods

| Period    | Forest (ha) | Forest (%)         | Mixed        |                    | RF (mm)              | Disch. (m <sup>3</sup> /dtk) | RO (mm)               | C (%)              |
|-----------|-------------|--------------------|--------------|--------------------|----------------------|------------------------------|-----------------------|--------------------|
|           |             |                    | Mixed G (ha) | Mixed G (%)        |                      |                              |                       |                    |
| 1999-2002 | 11200.2     | 39.3 <sup>a</sup>  | 8443.3       | 29.6 <sup>a</sup>  | 2,202.8 <sup>a</sup> | 161.6 <sup>a</sup>           | 1,451.5 <sup>a</sup>  | 20.0 <sup>a</sup>  |
| 2003-2006 | 9683.8      | 33.2 <sup>ab</sup> | 10408        | 36.5 <sup>ab</sup> | 1,603.6 <sup>b</sup> | 175.6 <sup>ab</sup>          | 1,558.2 <sup>ab</sup> | 21.0 <sup>ab</sup> |
| 2007-2010 | 8447.6      | 29.6 <sup>c</sup>  | 11976        | 42 <sup>c</sup>    | 1,744.4 <sup>b</sup> | 223.8 <sup>c</sup>           | 1,595.4 <sup>c</sup>  | 24.0 <sup>c</sup>  |

Remarks : Numbers followed by the same letter in the same coloum are not significantly different at  $\alpha=5\%$

The last periode (2007 - 2010) discharged of Mahat Hulu watershed more than the first periode (1999 - 2002) that was 223.8 m<sup>3</sup> / sec (periode 2007-2010) meanwhile in the periode 1999-2002 only 161.6 m<sup>3</sup> / s, which means rising 62.2 m<sup>3</sup> / sec. Results of water rose from 20 to 24, causing the larger the volume of water that can not be utilized and flows directly into the sea is estimated 113 million m<sup>3</sup> / sec (Figure 4)

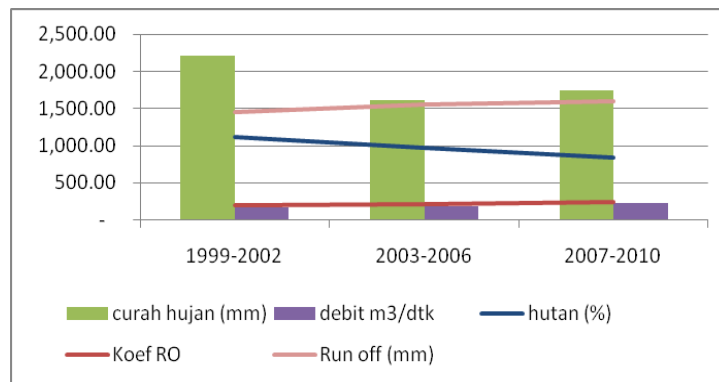


Figure 4 Forest and its effect on surface runoff in Mahat Hulu watershed

Run off coefficientt (C) during the rainy season is also different from the dry season in the same period. Table 4 shows the 1999-2002 period runoff coefficient (C%) is 20, while in the dry season 10. At the end of the period 2007 -2010 C (%) rainy season rose to 30%, while in the dry season is only 20%. This suggests that the impact deforestation during the rainy season led to increased surface flow is quite high compared to the dry season, which means also decrease the ability of the soil to infiltrate rainfall (Figure 5).

Table 4 Run off ccoefficient (C) based on season

| Period    | Forest (ha)          | Rainy season        |                    |                   |                     |                  | Dry season         |                   |                    |                  |
|-----------|----------------------|---------------------|--------------------|-------------------|---------------------|------------------|--------------------|-------------------|--------------------|------------------|
|           |                      | Mixed G (ha)        | RF (mm)            | Disc h (m3/dtk)   | RO (mm)             | C (%)            | RF (mm)            | Disch. (m3/dtk)   | RO (mm)            | C( %)            |
| 1999-2002 | 11200.2 <sup>a</sup> | 8443.3 <sup>a</sup> | 234.8 <sup>a</sup> | 17.3 <sup>a</sup> | 156.9 <sup>a</sup>  | 20 <sup>a</sup>  | 132.4 <sup>a</sup> | 7.9 <sup>a</sup>  | 72.2 <sup>a</sup>  | 11 <sup>a</sup>  |
| 2003-2006 | 9683.8 <sup>ab</sup> | 10408 <sup>ab</sup> | 179.4 <sup>b</sup> | 19.0 <sup>a</sup> | 179.5 <sup>ab</sup> | 27 <sup>ab</sup> | 114.9 <sup>b</sup> | 8.9 <sup>ab</sup> | 80.8 <sup>ab</sup> | 12 <sup>ab</sup> |
| 2007-2010 | 8447.6 <sup>c</sup>  | 11976 <sup>c</sup>  | 175.8 <sup>b</sup> | 20.4 <sup>a</sup> | 185.1 <sup>c</sup>  | 32 <sup>c</sup>  | 111.3 <sup>b</sup> | 11.3 <sup>c</sup> | 102.8 <sup>c</sup> | 24 <sup>c</sup>  |

Remarks : Numbers followed by the same letter in the same coloum are not significantly different at  $\alpha=5\%$

In the period 2007-2010 the forest area has been significantly reduced with the increase of mixed garden, this change implies that the higher erosion, discharge increased which in the rainy season 20.4. m3/sec and 11.3 m3/sec in the dry season. The high level of surface roughness and organic matter in the form of sarasah and dense canopy of the forest is the main factor reducing the effectiveness of forest runoff. Surface roughness, soil porosity and infiltration increased as a result of organic matter that accumulates on the surface and at the same time able to reduce run off.

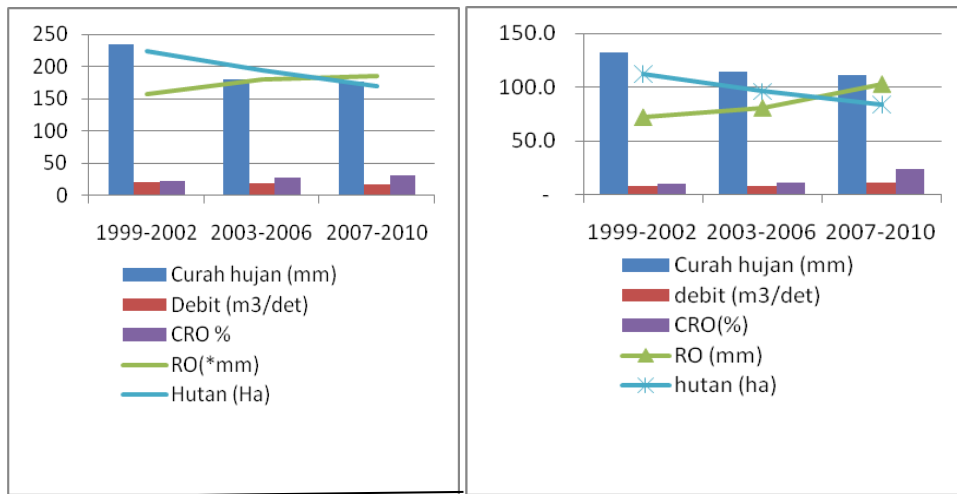


Figure 5 Forest and run off coefficient (rainy and dry season)

Tropudult typic soil types are dominant in the upstream watershed Mahat is also one type of soil that is dominated by clay and the ability to pass water infiltration is low to moderate (5.8 to 18.6 cm / h), permeability at speeds from 3.0 to 12 , 5 cm / h which characterizes the condition of the soil to pass a slow to moderate water, and dominated the slopes above 25% quasi characterize the biophysical conditions are not easily stored water and surface flow is quite high.

**Subsection 2**

Further analysis of the impact of land use change on hydrological conditions is to look at the relationship (correlation) between the value of C (%) with watershed land use Hulu Mahat (%). First with multiple regression analysis (*multiple regression*) are presented in the following equation.  $C (%) = 975 - 11.2 \text{ Forest} - 15.3 \text{ mixed G} - 10.9 \text{ shrubsr} + 0.43 \text{ dryland}$  dan  $R-Sq = 42.4\%$ , Stepwise Regression presented in the following equation  $C (%) = 31.5 - 0.370$  dan  $R-Sq = 5,3\%$ .

For regression was tested with a single and get the following equation:  $C (%) = 31.5 - 0.370$  dan  $R-Sq = 5,3\%$ ..Conclusion forest turns negative effect on runoff. The more extensive the forest, the less runoff proved that the hypothesis is accepted (Figure 6)

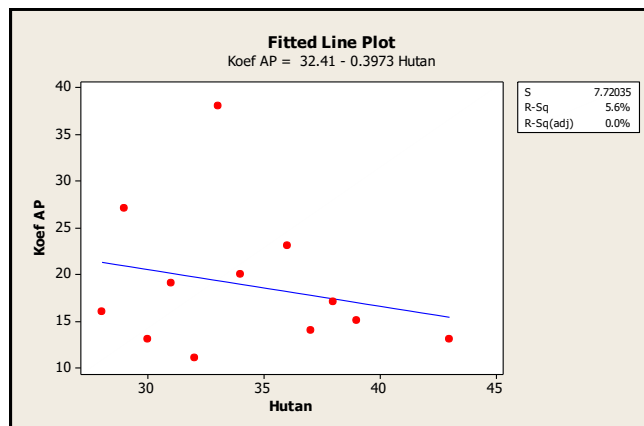


Figure 6 Simulation of forest and *run off*

Furthermore, by the equation  $C (\%) = 31.5 - 0.370 \text{ Forest}$  on simulation to estimate the impact of changes in land use change in the proportion of forest cover in particular the runoff coefficient (C) and estimates the value of lost water and that can be exploited Table 5

Table 5 Simulation of forest land use change on (C) and the estimation of water lost

| No. | Forest (%) | C (%) | RF (M / yr) | Water is lost million m <sup>3</sup> / yr | Value of water Billion / yr | Water used million m <sup>3</sup> / yr | Value of water (Billion / yr) |
|-----|------------|-------|-------------|---|-----------------------------|--|-------------------------------|
| 1   | 20         | 24.5  | 1.6         | 113.0                                     | 67,801.6                    | 387.0                                  | 464,396.8                     |
| 2   | 25         | 22.5  | 1.6         | 103.8                                     | 62,299.3                    | 396.2                                  | 475401.4                      |
| 2   | 30         | 20.5  | 1.6         | 94.7                                      | 56,797.0                    | 405.3                                  | 486,406.0                     |
| 4   | 35         | 18.5  | 1.6         | 85.5                                      | 51,294.7                    | 414.5                                  | 497,410.6                     |
| 5   | 40         | 16.5  | 1.6         | 76.3                                      | 45,792.4                    | 423.7                                  | 508,415.2                     |
| 6   | 45         | 14.5  | 1.6         | 67.2                                      | 40,290.1                    | 432.8                                  | 519,419.8                     |
| 7   | 50         | 12.6  | 1.6         | 58.0                                      | 34,787.8                    | 442.0                                  | 530,424.4                     |

Sources: H acyl simulated forest area and runoff price per m<sup>3</sup> of water = Rp. 1200. - (2012)

The increase forest cover in a watershed can reduce surface runoff coefficient (C), which in turn can increase the amount of water that can be utilized. This is because the forest is able to reduce runoff and increase infiltration capacity (Table 5). In accordance with the statement of Hewlett and Nutter (1969) that the upstream region is covered with forests better than 80-85% of the total flow from the base flow is sustained by the flow slowly from the *zone of aeration* the rest is direct flow (15-20%). Thus, the development of water resources with forest rehabilitation activities (reforestation) are implemented on watershed Mahat Hulu will be able to increase the availability of water for downstream communities, especially for hydropower Koto Panjang. In accordance with Law No. 41 of 1999 on forest area in the watershed of at least 30%, on research conducted fairly low runoff coefficient reached 20.5 %. To reduce runoff coefficient to be 10-15%, forested watershed areas to 45-50%. This is consistent with the results of the study Arief et, al (1991) showed that the *pine* forest watershed *Merkussi* have ground water reservoir thickness 312 mm and in agricultural watersheds on geological and topographical conditions of the same total soil water reservoir is only 27 mm while the watershed land cover mix in the area Cikapundung Gandok thick 241 mm soil water reservoir and the area Cigulung Marivaya on condition of mixed land cover 254 mm total water content, thus saving more forested watershed groundwater.

Subsequent analysis showed that changes in land use (PPL) or a decrease in forest area and increasing the use of mixed gardens and other cause the discharge increases the average daily maximum (Q max) and minimum discharge lowers the average daily (Q min) DAS Mahat Hulu. In this research, the testing of multiple regression analysis unakan use it again and get the equation  $Q_{max} HTN = 18 + 0.23 + 0.08 + 0.37 \text{ kbn.cmprn smk.blkr} - 0.92 \text{ tgln}$ . R-Sq = 1.0%. Results obtained turned out to woods, gardens and shrubs mixed Q shrub positive effect on the maximum and just moor negative influential. But through a single regression test which turned out to increase forest cover affects the maximum increase in Q while decreasing forest area does not affect the increase in maximum Q. Regression equation as follows.  $Q_{max} = 26.8 - 0.042 \text{ kbn.cmprn}$ . R-Sq = 0.5%



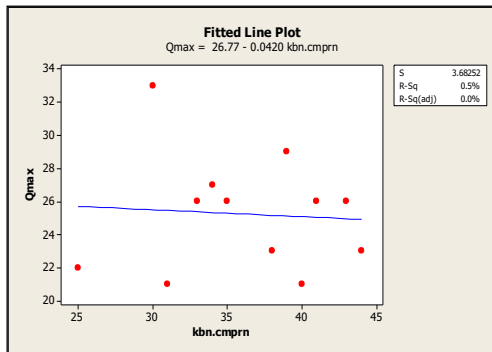


Fig 7 Simulation Q max with mixed garden

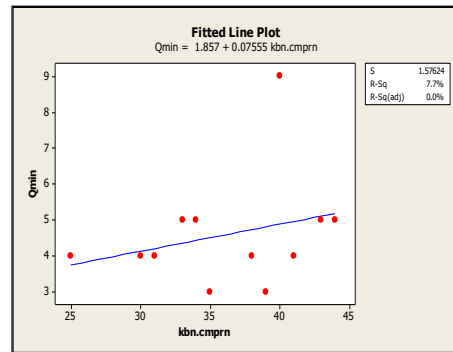


Fig 8 Simulasi Q min with a mixed

garden

Effects of changes in land primarily due to declining forest cover and increasing mixed gardens will also affect the minimum discharge ( $Q_{min}$ ). Regression test to get the following equation:  $Q_{min} = -55.1 + HTN + 0.61 \cdot 0.98 + 0.72 \cdot kbn.cmprn \cdot smk.blkr \cdot 0:35 \cdot tgln +$ ,  $R-Sq = 19.0\%$ . These results have not shown a variable effect on the minimum flow. To further stepwise test, but did not show satisfactory results, the next process via a single regression test found that the minimum  $Q$  would increase along with the breadth of mixed gardens (Figure 7 and 8). But the forest is inversely proportional,  $Q_{min} = 1857 + 0.07555 \cdot kbn.cmprn$ .  $R-Sq = 7.7\%$

According to Noordwijk VM. et al, (2004) Land cover by the tree in all its forms can affect water flow (discharge). Tree cover may be either a natural tree, plant or natural regeneration in the forest. Cultivated trees, trees as a hedge or tree monocultures (industrial plantations). Further, they say that the tree cover affects the flow of water in different stages such as: 1) interception, 2) protection of soil aggregates, 3) infiltration, 4) water uptake, and 5) landscape drainage.

This is consistent with the results of Pramod, I, B et.al (2010) who conducted a study in basin made from limestone parent KPH Cepu said that the peak discharge will change significantly involved in the event that the original forest area change 80% of the watershed area decreased to 53% watershed area, discharge peak rise of  $30 \text{ l / sec / km}^2$  becoming  $67 \text{ l / sec / km}^2$ . fact shows that the changes in the use of forest land to other uses contributed immensely to the increase in the maximum discharge average and volume of runoff. Furthermore, identifying activities pentupan land, needs to be deepened to measure the quality of its closure. This is because according to its function as a regulator of the water system, the possibility of mixed gardens can work together with forest, in other words the response of vegetated land cover types may be similar to rain On the other hand this leads to decreased soil water storage that will directly lower the minimum flow daily average.

Asdak, (2007) said that the function of the forest vegetation in regulating the hydrological environment occurs through the soil surface protection against the onslaught of rain kinetic energy, ie, through the 3 (three) layers of water storage areas, either by canopy strata (canopy) Sarasah forests, as well as pores forest soil, so that the water flow can be regulated. This is consistent with the proposed Sinukaban (2007), that the reduction in soil infiltration capacity erosion in the upper watershed caused replenishment ( *recharge* ) water under the ground ( *ground water* ) is also reduced, resulting in droughts in the dry season and floods during the rainy season .

Table 6 The effect of land use change to Discharged

| Period    | C (%)            | Discharged (m <sup>3</sup> /sec) |                   | Fluctuation Disch.<br>(Q <sub>max</sub> /Q <sub>min</sub> ) |
|-----------|------------------|----------------------------------|-------------------|---|
|           |                  | Rainy season                     | Dry season        |   |
| 1999-2002 | 20 <sup>a</sup>  | 17.3 <sup>a</sup>                | 7.9 <sup>a</sup>  | 2.4-5.5 <sup>a</sup>  |
| 2003-2006 | 21 <sup>ab</sup> | 19.0 <sup>b</sup>                | 8.9 <sup>b</sup>  | 5.6-5-8 <sup>a</sup>  |
| 2007-2010 | 24 <sup>c</sup>  | 20.4 <sup>b</sup>                | 11.3 <sup>b</sup> | 5.9-10.7 <sup>b</sup>                                       |

Remarks : Numbers followed by the same letter in the same coloum are not significantly different at  $\alpha = 5\%$

Land use changes in also causes increased fluctuation of the average daily Mahat Hulu watershed (1999-2010) that divided into 3 periode. For the first period (1999-2002) fluctuation of discharged only 2.4-5.5 but for the last periode (2007-2010) increased to 5.9-10.7. This proves that the land use change on the KRS is not only caused by reduced forest area but also due to the increased use of other mixed garden during the 12 years of observation of forest land use change to other land uses have made critical for Mahat Hulu watershed.

Ilyas (2000) reported that, the decline in the forest area in East Kalimantan Karangmumus watershed of the area of 18% to 10% can cause an increase in flood peak rate of 7.6% of the original condition. While Sinukaban N, Satjapradja, and Wastra (2007) states that the change in land use bush into *agroforestry* (mixed gardens) in Sub-watershed Manting East Java has led to an increase in the coefficient of river regime (KRS) or fluctuations in surface runoff from 9.7 in 1987 to 10.1 in 1988 and to 13.1 in 1999. This is because agroforestry or mixed gardens that applied causing some land to be open, so the impact on the increase in surface runoff.

## Conclusion

1. Mahat Hulu watershed forest decreased significantly over the last 15 years. During the early period 1999-2002 still dominant forest area is 11200.2 ha (39.3%), and mixed garden 8443.3 ha (29.6%), and another 8891.5 ha (31.111%), but in the last periode (2007-2010) the forest area decreased to 8447.6 ha ( 29.6%) fell 9.6% (2752.6 ha), mixed gardens increased to 11976 ha, up 12.4% (3532.7 ha) and another 8111.4 ha (28.43%).
2. Deforestation has been influence aspects of hidrology eg, a) Run off coefficient increasing from 20% in the 1999-2002 period to 24% in the period 2007-2010. b) increasing discharged from 161.6 m<sup>3</sup>/sec (1999-2002) to 223.8 m<sup>3</sup>/sec. c) Deforestation also increasing Q max.and d) Increasing discharged fluktuation from 2.4-5.5 (1999-2002) to 5.9-10.7 (2007-2010 and the last, water lost around 113 million m<sup>3</sup>/year ( Rp.67.8 M/year) cause by increasing run off coefficient
3. Land use change (deforestation) has led to high sedimentation in reservoirs PLTA Koto Panjang Koto Panjang. Its impact is loss of hydropower from 3 GWh -30 GWh in a month.
4. Improving traditional mixed gardes systems by using agrotechnology strip cropping and mulch systems reduce erosion rate under tolerable erosion is 32.82 ton/ha/year meanwhile E-tol is 39.6 ton/ha/year.

## Acknowledgments

Gratitude to Allah SWT was allowed me to completely this research. Thanks also toThe Rector of Muhammadiyah University West Sumatera that support me to research. Research aimed at examining land use issues in the upper site of the Mahat watershed shows a satisfying result where incorrect land management has caused environmental problems, especially high surface runoff and flooding. Thank's also to Prof. Dr. Ir Naik Sinukaban who contributed a lot of thought about

Hydrology and Prof. Dr.Ir. Kukuh Murti Laksoo with the watershed management and friends who are members of the West Sumatra watershed forum who have contributed a lot of their thoughts about the critical condition of the Mahat watershed. Finally, many thanks to reviewers who helped review this paper for publication in international journals, especially International of Journal's Psychosocial Rehabilitation.

The completion of this research is expected to help the parties, especially policy makers, make use of data and information obtained to overcome problems in the Mahat river watershed.

Thank you for all.

Padang, March, 26, 2020

Firman Hidayat

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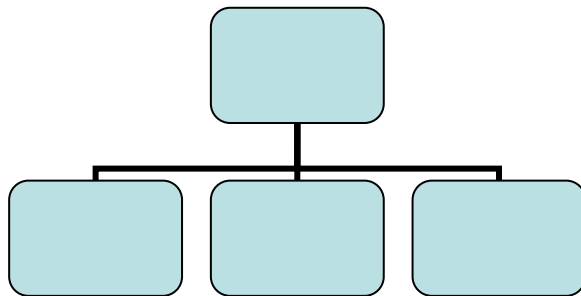
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## **Acknowledgments**

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<https://doi.org/10.1007/978-3-540-30300-8>

Fischli, A. E., Godfraind, T., & Purchase, I. F. H. (1998). Conclusions and Recommendations. Pure and Applied Chemistry, 70(9), 1863-1865.

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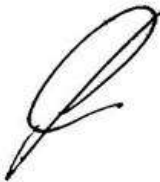
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