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Sumantri Brojonegoro 1, Bandar Lampung 35145, Indonesia Abstract This research aimed to model groundwater level (GWL) fluctuation in the tropical peatland areas under the effect of El Nino Southern Oscillation (ENSO). The focus of the study was the peatland area between Sebangau River and Kahayan River, Central Kalimantan Province

Indonesia. One-dimensional GWL model was developed using Excel in order to simulate the GWL fluctuation of 4 GWL observation wells which were Swtr2, Swtr3, Swtr4, and Swtr6.

The model was calibrated for the dry season 2011 and, after that, was used to model GWL fluctuation in El Nino year of 1997 and 2002. The model showed very good performance in simulating GWL fluctuation of 4 observation wells in the dry season condition where the GWL were under the ground level elevation. The model indicated that in the El Nino years of 1997 and 2002, the GWL in the observed area in the dry season dropped significantly due to the absence of rainfall in the area.

Based on the model, the fire risk in the tropical peatland areas can be measured and predicted © 2012 The Authors. Published by Elsevier B.V. Selection and/or peer-review under responsibility of SUSTAIN conferences committee and supported by Kyoto University; (OPIR), (GCOE-ES), (GCOE-HSE), (CSEAS), (RISH), (GCOE-ARS) and (GSS) as co-hosts. Keywords: Groundwater fluctuation model; ENS; tropical peatland areas 1. Introduction El-Nino Southern Oscillation (ENSO) is a climate phenomenon that is associated with sea surface temperature anomalies in the waters of the Pacific Ocean.

ENSO leads to changes in temperature and precipitation. In Indonesia ENSO caused drought in most parts of the regions. In the year 1997/1998 ENSO event has caused the most severe forest fires around the world including Indonesia. Based on * Corresponding author. Tel.: +81-80 4-269-8546. E-mail address: n502wf@yamaguchi-u.ac.jp or gatot89@yahoo.ca. Available online at www.sciencedirect.com © 2013 The Authors. Published by Elsevier B.V. Open access under CC BY-NC-ND license. Selection and peer-review under responsibility of SUSTAIN conference's committee and supported by Kyoto University; (OPIR), (GCOE-ES), (GCOE-HSE), (CSEAS), (RISH), (GCOE-ARS) and (GSS) as co-hosts. 120 Gatot Eko Susilo et al.

/ Procedia Environmental Sciences 17 (2013) 119 – 128 research conducted by Bappenas and the Asian Dev elopement Bank [1], widespread forest fires in Indonesia caused by ENSO events during the year reached 9.75 million ha [2]. Of the total area of forest burned, it was 1.46 million ha of peatlands that were scattered on the islands of Kalimantan (0.75 million ha), Papua (0.40 million ha) and Sumatra (0.31 million ha). Forest fire in the peatland areas is very important to note. Peat lands are the world largest carbon source.

When the fire happened in the peat forest, organic carbon (C) becomes carbon dioxide (CO 2) and it will be released to the atmosphere in very large quantities and becoming

green house gases as a fuel of global warming. Changing peatlands into agricultural and residential areas will change the pattern of groundwater in the area of peat. Construction of drainage channels ca uses a drop in the groundwater in the peat soil. Furthermore, the decline in ground water will lead to increased risk of forest fires due to dry peat.

Under these conditions, studying the behavior of groundwater in the peat in order to maintain a high water table and reduce the risk of forest fires is a very important thing to do. The best way to monitor the behavior of groundwater is to directly measure the groundwater in monitoring wells. However, cost and effort required to conduct monitoring of groundwater behavior in a long time with an adequate measurement point. There were limited numbers of groundwater parameters of peat swamp areas have been readily measured in the field [3].

Yet, research concerning the ap plication of groundwater models to wetland hydrologic systems have been rarely undertaken, es pecially for tropical peat swamp areas, and only few publications have been found on this important subject [4]. An alternative method for predicting the effect of hydrological parameter on groundwater level (GWL) behavior in the wetland is by modeling the system. By modeling we hope to describe an event in the past based on a schematic description, theory, or phenomenon of a same system with different data. Therefore, this research aims to model GWL fluctuation in the pe atland areas in the past.

The focus of this research is to model GWL fluctuation under the effect of ENSO and investigate its relation to the risk of forest fire. The area of the study is the peatland area on the area between Sebangau River and Kahayan River. The area is located between coordinates of 114.01 o E, 2.28 o S and 114.09 o E, 2.37 o S. The area is known as the Block C of ex Mega Rice Project area, in Central Kalimantan Province, Indonesia. 2. Methodology 2.1. Study site and data Figure 1 showed the study area, the Block C of ex Mega Rice Project area, in Central Kalimantan Province, Indonesia. In this area, in 1995, Indonesian Government launched a project called Mega Rice Project in Central Kalimantan.

The launching of the project aimed to save the national food program by changing peatland areas into paddy field areas. However, in 1999 the government had stopped the project under the suggestion of several international foundation and some investigations carried out by the some government institutions. The main reason of the project discontinued was that the development of peatland areas would destroy the peatland environment and drain the water in the peatlands.

Drainage of the peatswamps will lead to rapid decomposition of th e organic carbon of the peat and to annual peat fires. This degradation has a devastating impact on the means of air pollution in South-east Asia and last but not least climate change as huge quantities of organic carbon becomes carbon dioxide. Emissions from degraded peatland areas will continue until a ll peat has disappeared [5]. A decade after the launching of the project, the areas became drained areas and turn to be abandoned forest areas.

Nowadays, the project of peatland development changes into peatland restoration project in order to save peatland areas in Central Kalimantan. Some international organizations have been involved in the areas with aim to restore the peatland. 121 Gatot Eko Susilo et al. / Procedia Environmental Sciences 17 (2013) 119 – 128 Groundwater level (GWL) for this research was measured using automatic gauge (OYO S&DL mini) installed in the wells by Center for International Cooperation in Sustainable Management of Tropical Peatland (CIMTROP) of Palangkaraya University, In donesia and Center for Sustainability Science (CENSUS) of Hokkaido University, Japan.

Daily GWL data was used for daily simulation in the modeling and was extracted from hourly GWL data th at had been recorded between June and September 2011. In order to find the real fluctuation of GWL due to rainfall and evapotranspiration on the observed area, the GWL data used for simulation had to be th e one which the elevation is under the elevation of ground level for every groundwater wells. In detail, the description of each well is presented in table 1 and figure 1. 5 km Swtr2 Swtr3 Swtr4 Swtr6 Kalampangan Canal Taruna Canal Sebangau River Kahayan River Fig. 1. Study site and groundwater observation wells location. Table 1.

Location of each well and its land cover No. Point Latitude S Longitude E Ground level (m) Vegetation Starting date of simulation Last date of simulation 1 Swtr2 2.3548 114.0297 19.81 Natural forest 6/1/2011 8/15/2011 2 Swtr3 2.3479 114.0361 20.16 Natural forest 7/1/2011 9/30/2011 3 Swtr4 2.3407 114.0428 19.31 Grassland 7/1/2011 9/30/2011 4 Swtr6 2.3212 114.0586 18.56 Grassland 7/1/2011 9/30/2011 122 Gatot Eko Susilo et al. / Procedia Environmental Sciences 17 (2013) 119 – 128 Hydrological data used in this resear ch was daily rainfall data and daily temperature data. Both types of data were obtained from the local hydrological station in the location of study. 2.2.

Modeling procedures One-dimensional GWL model was developed using Excel in order to simulate the GWL fluctuation of 4 GWL observation wells. The stations are Swtr2, Swtr 3, Swtr4, and Swtr6. The water balance equation xpressed as [6]: (1) where P is precipitation, Q is the sum of surface runoff, transp iration, interflow, and surface detention, E is evapotranspiration, is the change in storage of groundwater. When the

calculation is only focused on the groundwater recharge process in the unsaturated and saturated zone, the value of Q can be neglected. It is because all component of Q are soil surface processes.

For GWL fluctuation model for in this particular research, the water balance equation under specific time period ( ) is expressed as: (P-Q)/Sy ETo.Kc/Sy (2) where is the increase/decrease in GWL, ETo is reference evapotranspiration, Kc is crop coefficient, and Sy is specific yield of the soil. The system of the GWL model can be illustrated in the Figure 2. Soil column in the figure 2 is considered uniform soil and ho is initial condition of GWL. Boundary condition of the system is that there is no flux from or to the right side, left side, and the bottom of the system.

The top of the system is atmospheric boundary layer the area between ho an d soil surface is consid ered unsaturated zone. Oppositely, the area below ho is saturated zone and the bottom of the system is impermeable area. (P-Q)/Sy ETo.Kc/S Initial GWL (ho) GWL after recharged (h1) Boundary of impermeable layer h=h1 -ho Ground level P Q Fig. 2. Diagram showing the method of GWL fluctuation mechanism used in the model. 123 Gatot Eko Susilo et al. / Procedia Environmental Sciences 17 (2013) 119 – 128 2.3. Evapotranspiration calculation Based on the availability of the data, the Hargreaves method was used in this research for estimating ETo.

The Hargereaves equation can be expressed as [7]: ETo = 0.0023(Tmean+17.8)(Tmax Tmin)0.5Ra (3) where ETo is the daily reference evapotranspiration (mm/day), Tmax and Tmin are the maximum and minimum daily temperatures, respectively (C), Tmean is the mean temperature (C) and Ra is the extraterrestrial radiation (MJm2/day). 2.4. Model calibration and evaluation The model was calibrated using GWL data reco rded between June and September 2011. The calibration process is undertaken by adjusting C, Kc, and Sy parameter values into the best fit of the observed and calculated GWL.

The best fit of the mod el is indicated by the highest value of the Nash- Sutcliffe Efficiency Index for the simulation of all observed well. McCuen et al. [8] has demonstrated that the Nash-Sutcliffe Efficiency Index is comparable to the coefficient of determination (R 2) and its use is recommended for non-linear modeling problems [9]. This coefficient is defined as: = 1 - [(x-y)2/[(y- 2] (4) where x is obse maximum value is 1.0, which means a perfect match of modeled data with th e observed data. If the value is equal to 0.0, the model predictions will be as accurate as the mean of the observed data. 3.

Results and discussions The value of Kc and Sy for the best fit of model for every data series of calibrated year is presented in table 2, and graphical presentation of model

simulation results was given in the appendix A. The model showed very good performance in simulating GWL fluctuation of 4 observation wells in the dry season condition where the GWL were under the ground level elevation. Table 2. The value of Kc and Sy for the best fit of model for every data series calibrated for year 2011 Site Initial Q Kc Sy R2 Swtr2 0.74 0.75 0.40 0.92 0.92 Swtr3 0.74 0.53 0.30 0.86 0.86 Swtr4 0.10 0.59 0.38 0.81 0.81 Swtr6 0.14 0.60 0.40 0.87 0.87 The model, furthermore, was used to simulate the GWL for El Nino year of 1997 and 2002 for the period of July 1 st to October 30 th. The initial condition of GWL in every simulation was assumed equal to ground level.

Graphical presentation of model simulation results was given in the appendix B and C. 124 Gatot Eko Susilo et al. / Procedia Environmental Sciences 17 (2013) 119 – 128 There were several characteristics that can be identified from the condition of groundwater level on the area observed. The most prominent characteristic wa s that in the El Nino year position groundwater always below ground level for a period of more than 3 months.

It is not too surprising because the amount of precipitation in the dry season of El Nino years was generally smaller than the ones in normal years. Rainfall greater than 10 mm were rare and this circumstance result ed in a negative water balance. Moreover, in 1997, the rainfall was more than 10 mm only happened twice in the period of the simulation and the distance events with more than 3 months. Th e graphs in the appendix B and C also showed that the GWL in the observation wells dropped significantly du e to the absence of rainfall in the area.

Ideally, to prevent the peatland area from the risk of peat fi res, the water table cannot be more than 40 cm below the soil surface. If the groundwater level in tropical peat drops below 40 cm from the surface, the moisture content of the little humified top layer decreases drastically from about 0.90 cm 3/cm3 at saturation to about 0.50 cm 3/cm3 at a This situation will lead to peat fires because the fire spread quickly in dry peat soil [10][11][12][13]. Forest fires are an annual occurrence in Indonesia duri ng the dry season.

Most of the forest fires, both ordinary and peatland forest, caused by human activities in the context of land clearing or logging. But in recent years, forest fires caused by natural disasters such as droughts become an interesting topic to talk about. Especially after a major fire incident in the year 1997/1998, natural factors such as ENSO became a focus of the attention in the preven tion and mitigation of global forest fires in Indonesia. El Nino in Indonesia can be monitored by continuous observatio n of sea

surface temperature (SST) anomalies over central and east Equatorial Pacific several months be fore the event happens.

The use of remote sensing data has been intensively undertaken to monitor SST anomalies in order to detect the event of El Nino globally in Indonesia [14]. Until now, monitoring and modeling of groundwater level in peat lands in Indonesia for the purpose of anticipating forest fires have not been implemented. In fact, an accurate modeling of groundwater for peatland may serve as an indication of the position GWL elevation. Furthermore, the possibility of peat fires can be detected based on the state of the GWL.

Detection possibility of peatland fires via GWL model will also provide more detailed information about the status of a regional fire risk than global information obtained from satellites. There are three im portant things that should be available in the modeling of ground water in peatland. They are th e rainfall data, temperature data, and GWL data. All must have good accuracy and a sustained period. Di rect monitoring of the GWL in peatland areas may require a substantial investment. But the cost of the investment will be very small compared to the benefits of the land saved from the fire.

However, fore st fire in peatland is quite complex to be resolved. A technology or method cannot stand alone to handle this problem. The combination of technologies and methods, both technical and non-technical, is probably the most recommended way in the prevention and management of fires in peatland area in Indonesia. 4. Conclusion The ENSO has significant effect on GWL and fire risk in the peatland. The fire risk in the tropical peatland areas can be measured and predicted based on GWL fluctuation model.

The model in this study showed that in the years of El Nino, the elevatio n of groundwater in the area observed decreased dramatically, especially in the dry season. The decline was more than 40 cm below the soil surface. This means the possibility of a peat fire danger is high fo r this area. In the future, this kind of models are expected to be used to determine the level of fi re hazard possibility of pe atland and can serve as a reference in determining the strategy in handling of peatland fires in Indonesia. 125 Gatot Eko Susilo et al.

/ Procedia Environmental Sciences 17 (2013) 119 – 128 5. Acknowledgement The authors thank Dr. Hidenori Takahashi of the Hokkaido Institute of Hydro-Climate for supplying excellent hydrological data for this re search and JST/JICA for financin g the project. The first author wishes to acknowledge support from the Director ate General

of Higher Education of Republic of Indonesia who finances him to carry out this research in Yamaguchi University of Japan. References [1] BAPPENAS-ADB.

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Monitoring El Nino and La Nina phenomenon: the use of remote sensing for land forest fire anticipation. Warta LAPAN 2001, 3(2): 45-55. 126 Gatot Eko Susilo et al. / Procedia Environmental Sciences 17 (2013) 119 – 128 Appendix A. GWL modeling for calibrated year 2011 18.00 18.50 19.00 19.50 20.00 20.50 6/1/2011 7/1/2011 7/31/2011 Elevation (m) Date SWTR2 GL Obs Mod 18.00 18.50 19.00 19.50 20.00 20.50 7/1/2011 7/31/2011 8/30/2011 9/29/2011 Elevation (m) Date SWTR3 GL Obs Mod 18.00 18.50 19.00 19.50 20.00 20.50 7/1/2011 7/31/2011 8/30/2011 9/29/2011 Elevation (m) Date SWTR4 GL Obs Mod 18.00 18.50 19.00 19.50 20.00 20.50 7/1/2011 7/31/2011 8/30/2011 9/29/2011 Elevation (m) Date SWTR6 GL Obs Mod 127 Gatot Eko Susilo et al.

/ Procedia Environmental Sciences 17 (2013) 119 – 128 Appendix B. GWL modeling for El Nino year 1997 18.00 18.50 19.00 19.50 20.00 20.50 7/1/1997 7/31/1997 8/30/1997 9/29/1997 10/29/1997 Elevation (m) Date SWTR2 GL Mod 18.00 18.50 19.00 19.50 20.00

20.50 7/1/1997 7/31/1997 8/30/1997 9/29/1997 10/29/1997 Elevation (m) Date SWTR3 GL Mod 18.00 18.50 19.00 19.50 20.00 20.50 7/1/1997 7/31/1997 8/30/1997 9/29/1997 10/29/1997 Elevation (m) Date SWTR4 GL Mod 18.00 18.50 19.00 19.50 20.00 20.50 7/1/1997 7/31/1997 8/30/1997 9/29/1997 10/29/1997 Elevation (m) Date SWTR6 GL Mod 128 Gatot Eko Susilo et al. / Procedia Environmental Sciences 17 (2013) 119 – 128 Appendix C. GWL modeling for El Nino year 2002 18.00 18.50 19.00 19.50 20.00 20.50 7/1/2002 7/31/2002 8/30/2002 9/29/2002 10/29/2002 Elevation (m) Date SWTR2 GL Mod 18.00 18.50 19.00 19.50 20.00 20.50 7/1/2002 7/31/2002 8/30/2002 9/29/2002 10/29/2002 Elevation (m) Date SWTR3 GL Mod 18.00 18.50 19.00 19.50 20.00 20.50 7/1/2002 7/31/2002 8/30/2002 9/29/2002 10/29/2002 Elevation (m) Date SWTR4 GL Mod 18.00 18.50 19.00 19.50 20.00 20.50 7/1/2002 7/31/2002 8/30/2002 9/29/2002 10/29/2002 Elevation (m) Date SWTR6 GL Mod

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