ENERGY AND WATER BALANCE AROUND LORE LINDU NATIONAL PARK IN CENTRAL SULAWESI, INDONESIA

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Abstract

Some efforts to protect conservation areas had been done but research on quantification of impact of land use/land cover change is still needed. Mainly in the conservation areas around Lore Lindu National Park (*LLNP*) in Central Sulawesi Province, Indonesia where the difference in energy and water balance characteristics occurred as a consequence of land use and land cover change. Six land unit types as margins areas at different altitudes were used such as open area in Palu, rice field in Gimpu-Pandere, cacao plantation in Nopu, grass and open areas in Talabosa, vegetables in Watumaeta, and tropical mountain forest in Rore Katimbu. The indication of land use/land cover change can be detected based on both Bowen Ratio (Beta, *b*) and fraction of availability energy (Alfa, *á*) from energy balance component, and also by deficit and surplus from water balance component. Based on these criteria, the values of Beta and Alfa in these areas were different for every location. The value of Beta in open areas is higher than vegetation areas, but vice versa for the value of Alfa. Combinations of Beta and Alfa (*b*, *á*) for six location were Palu (1,05;0,58), Gimpu-Pandere (0,50;0,67), Nopu (0,09;0,91), Talabosa (0.46;0,67), Watumaeta (0,56;0,63), dan Rore Katimbu (0,60; 0,91).

Based on daily scale, the average values of energy reaching the surface around LLNP were 19.9 $MJm^{-2}day^{-1}$ for global radiation, 11.9 $MJm^{-2}day^{-1}$ for net radiation, 3.5 $MJm^{-2}day^{-1}$ for sensible heat flux, 7.9 $MJm^{-2}day^{-1}$ for latent heat flux, and 0.5 $MJm^{-2}day^{-1}$ for soil heat flux. It showed that about 60% of global radiation was converted into net radiation. The available energy from net radiation was used more as latent heat for evaporation (66%), than as sensible heat (29%) and soil heat flux (< 1%). The energy balance Bowen ratio (*EBBR*) method agreed with Penman-Monteith (PM) method to estimate daily of evapotranspiration (*ETP*) around of LLNP. The value varied from 2.0 to 4.0 mm/day. It means that energy balance Bowen Ratio can be used as estimator of evapotranspiration in this region. This paper also explained about the possibility to apply Solar Analyst Model in distribution of energy balance components in the research area.

Keywords : *energy balance, water balance, Bowen ratio, evapotranspiration, Lore Lindu, Central Sulawesi*

Introduction

Generally, land use change is from forest to become non forest such as agriculture, housing, and industrial regions. The changes result to direct and indirect impacts which further and then cause global heating and climate variation. The direct impact covers the changes of energy balance, water and nutrient, while the indirect impact is the increase of greenhouse gases.

On the other hand, the water balance covering rainfall component (R_f) as source of water increment, potential evapotranspiration (*ETP*) and soil water content (*SWC*) shows the increase and decrease of water on a surface. Hence, a study on the evapotranspiration component which becomes a chain between energy balance and water balance.

The objectives this research were (1) to study the effects of climate variation, land use change, and topographic condition on the distribution of energy and water balance around of *LLNP*; (2) to study the change of energy and water balance values in the diurnal and daily scales to characterize a location; (3) to study the feasibility of Energy Balance Bowen Ratio (*EBBR*) method as estimator of evapotranspiration in tropical and mountainous areas.

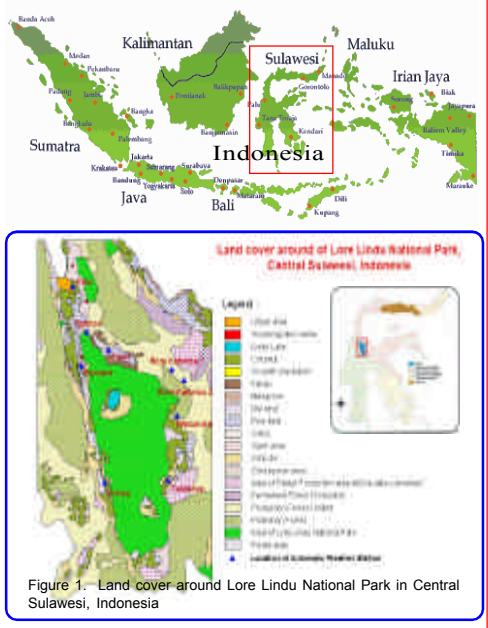
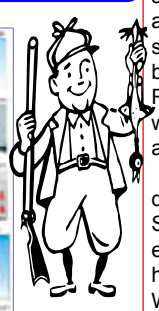


Figure 1. Land cover around Lore Lindu National Park in Central Sulawesi, Indonesia

Figure 2. Six types land unit were used as reseach locations around of Lore Lindu National Park, in Central Sulawesi such as open area. rice field, cacao plantation, grass area, vegetables, and mountain tropical forest.

Figure 3. EnergyBalance Bowen Ratio Method is used with some sensors of Automatic Weather Station; Nett Radiometer,Soil Heat Flux meter, RH&T Screen.



Result and Discussion

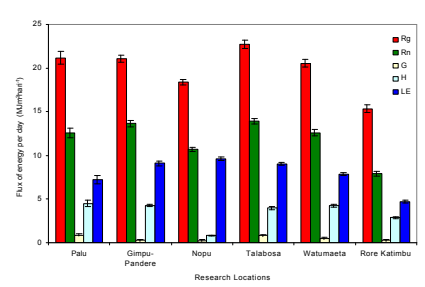


Figure 5. Variation of energy balance component for six selected locations around LLNP in Central Sulawesi, Indonesia during five months measurement (December 2001-April 2002).

Palu Valley received energy flux intensity of Rg and Rn equal to Palolo and Besoa Valley. The difference occurred on Napu Valley or mountainous regions represented by Rore Katimbu. The location of Talabosa was uniqueness because at elevation about 1000 m above sea surface but having similarity in acceptances of Rg and Rn with Palu and Gimpu-Pandere. Soil heat flux was not significantly different at each location except between Palu with Rore Katimbu and Nopu with Rore Katimbu. Energy balance components which were significantly different among locations were atmosphere heating and evaporation latent heat.

Five important points related to energy balance dynamic at a surface of around LLNP, Central Sulawesi. Firstly is atmosphere heating process and evaporation indicated by H and LE values which had higher value at day i.e. 70.0 Wm^{-2} and 156.5 Wm^{-2}, respectively.

Secondly is the result of available energy conversion is more used in form of latent heat than sensible heat. However, for evaporation process it still needs water availability from soil and plant. For example the condition in Nopu, almost 90% available energy at every day was used for evaporation even though this area in dry climate type (E, F or G) as well as Gimpu-Pandere. However, water availability in the soil still needed. If soil water was not available, the net radiation will used more for sensible heat than latent heat. Then, the sequence of usage was atmosphere heating followed soil surface heating

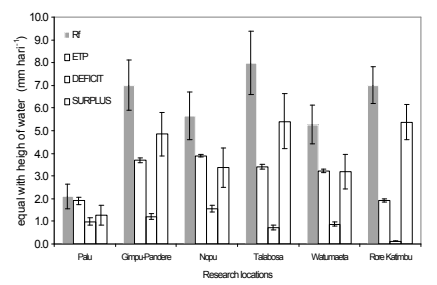


Figure 6. Variation of water balance component for six selected locations around LLNP in Central Sulawesi, Indonesia during five months measurement (December 2001-April 2002).

Thirdly is the occurrence of energy release at night dominated by soil surface (G) into atmosphere.

Fourthly is the occurrence of proportion change of energy balance component in the morning and afternoon (approaching night).

Fifthly is proportion of energy balance component on Rn is also varied from time to time either in daily scale or monthly scale. This difference is affected by weather condition especially related with cloudiness process and rainfall so that the change in energy input from global radiation will cause a change in energy magnitude available for latent heat flux, sensible heat flux, and soil heat flux.

The indication of land use/land cover change can be detected based on both Bowen Ratio (Beta, *B*) and fraction of availability energy (Alfa, *a*) from energy balance component, and also by deficit and surplus from water balance component. Based on these criteria, the values of Beta and Alfa in these areas were different for every locations. The value of Beta in open areas is higher than vegetation areas, but vice versa for the value of Alfa. Combinations of Beta and Alfa (*b*, *á*) for six location were Palu (1,05;0,58), Gimpu-Pandere (0,50;0,67), Nopu (0,09;0,91), Talabosa (0.46;0,67), Watumaeta (0,56;0,63), dan Rore Katimbu (0,60; 0,91) (Figure 7).

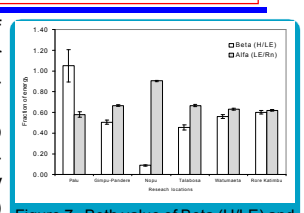


Figure 7. Both value of Beta (H/LE) and Alfa (LE/Rn) as a tool to identifiy impact of land use/land cover change at six selected locations around Lore Lindu National Park in Central Sulawesi, Indonesia.

Methodology

Site Descriptions

This research was conducted around Lore Lindu National Park located at 120°03' East Longitudinal and 01°20' South Latitude and 300 – 1700 m altitude. Nine Automatic Weather Stations (AWS) were installed around Lore Lindu National Park at six locations, i.e. Palu, Gimpu-Pandere, Nopu Talabosa, Watumaeta, dan Rore Katimbu. The determination of these locations were based on climate type, elevation, and vegetation dominating the locations consisting of open soil, rice field, meadow, cacao plantation, and montaineous forest (see Figure 1 and 2 for research locations).

This research resulted three important things as follows: (1) the quantitative value of energy and water balance of the region, (2) the factors which were influencing the change of energy and water balance at that region, as well as (3) the ability of Bowen Ratio method as estimation technique of energy balance and evapotranspiration in tropical and mountainous areas.

Equipments

We instaled nine automatic weather station (AWS) and aditional sensor of temperature to follow of the rule of EBBRM (see Figure 3 for instrumentations).

Energy Balance

$$Rn - H_{EBBRM} - LE_{EBBRM} - G = 0$$

$$\beta = \frac{H}{LE} = \frac{Pc_p}{LE}\left(\frac{Kh}{Kw}\right)\frac{\partial T/\partial Z}{\partial e/\partial Z} \quad ; \gamma = \frac{Pc_p}{LE}$$

$$= \gamma \frac{Kh}{Kw}\frac{\partial T/\partial Z}{\partial e/\partial Z}$$

$$\beta = \gamma \frac{\partial T}{\partial e}$$

Energy Balance Bowen Ratio Method (EBBRM)

$$H_{EBBRM} = \frac{1+b}{b}(Rn-G)$$

$$LE_{EBBRM} = \frac{1}{1+b}(Rn-G)$$

Criteria of Bowen value is used based on Ohmura (1982);Perez *et al*., (1999); Todd *et al*., (2000); Liu and Foken (2001).

Water Balance $Rf = ETP \pm SWC$

$$k = P_0 + \frac{P_1}{WHC}$$

$P_0 = 1.000412351$

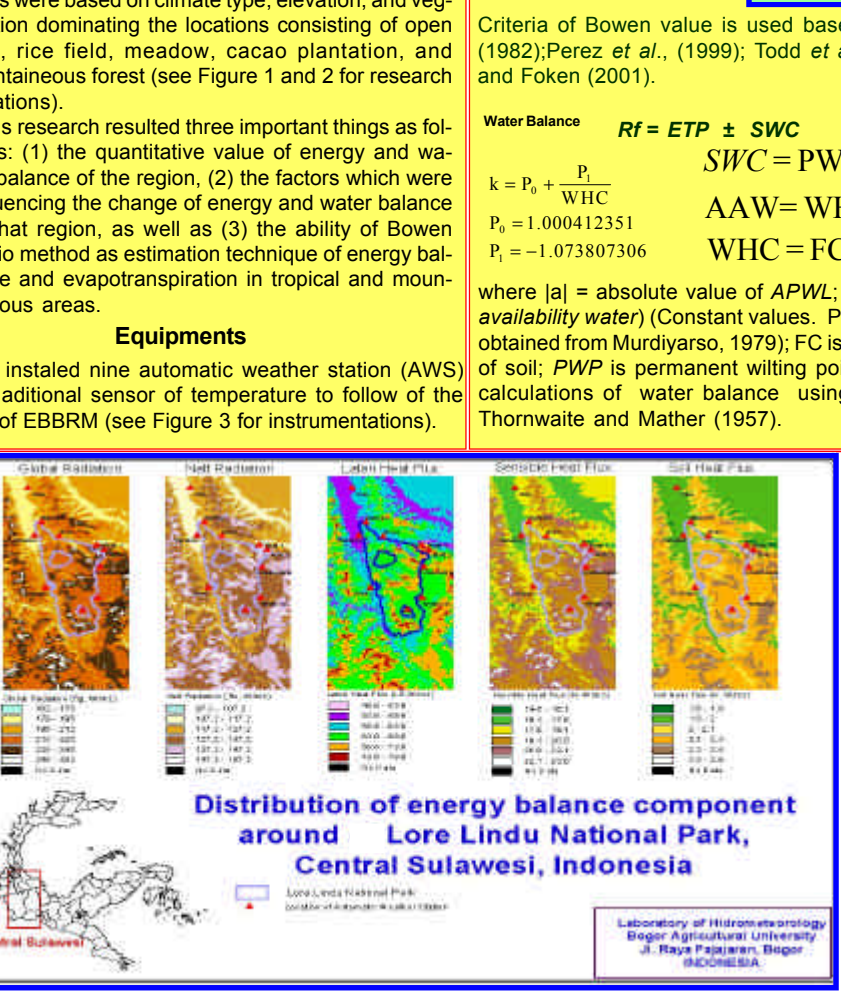
$P_1 = -1.073807306$

$$SWC = PWP + AAW$$

$$AAW = WHC \times k^{|a|}$$

$$WHC = FC\text{-}PWP$$

where |a| = absolute value of *APWL*; *AAW* (*Actual availability water*) (Constant values. P_0 and P_1 were obtained from Murdiyarso, 1979); FC is field capacity of soil; *PWP* is permanent wilting point of soil. All calculations of water balance using principle of Thornwaite and Mather (1957).



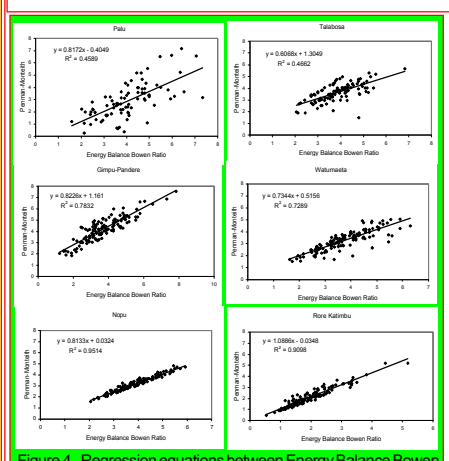


Figure 4. Regression equations between Energy Balance Bowen ratio method and Penman-Monteith method for estimating value evapotranspiration at six selected locations around LLNP in Central Sulawesi, Indonesia.

Suggestions:

Based on this research, there are two suggestions as follows: (1) If Energy Balance Bowen Ratio method will be used as indicator of impact of land use/land cover change in certain location, user needs to know the time scale that will be used i.e. diurnal scale for micro climate study and daily scale for regional study; (2) This study should be used to help in environmental management of Lore Lindu National Park especially to avoid disaster when the rainy season or if the forest area will be converted to non forest area. The use of energy balance method of Bowen Ratio needs to be considered advection factor to avoid energy input from horizontal direction influencing calculation of energy balance. An alternative is by considering the use of accurate and sensitive instrumentation.

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