Research project of counterparts funded at IPB

Name	Counterpart	Title
Tania June, Ummu Marufah	**A03**	Evaluating the impact of land-use changes on land-atmosphere interaction including heat fluxes, Gross primary and Net Primary production and Coupling Strength in Jambi Province using CLM 5.0

Background and Objectives

Land surface is an essential element of the earth system, regulating the energy,water and carbon cycle. Each type of land surface undergo dissimilar biogeophysical and biogeochemical processes and therefore they will have different microclimates in controlling the carbon and water cycle. A change in land use will alter these processes.

From 1990 to 2012, Indonesia have lost about 20,7 Mha of forest area and Sumatra contributes to 8.6 Mha or about 41.5% of total national deforestation (Wijaya et al. 2015). One of the areas with extensive forest transformation is Jambi Province, with the decline in primary and secondary forest area being approximately 38,2% and 30,9% respectively within the period of 1990 to 2013 (Melati 2017). Usually, forest conversion starts from shrubs, grasses, or dryland agriculture and after some period, change into rubber and oil palm or other monoculture types.

The objectives of this research are to evaluate the impact of land use change (from forest to schrub, grass and soybean) on sensible heat flux (H), latent heat flux (LE), gross primary production (GPP) and net primary production (NPP) using Community Land Model (CLM 5.0) and how it changes the coupling strength between soil moisture and surface fluxes (latent heat/water fluxes) of these different types of land use.

Methodology

The general procedure of the research is shown in Figure 1. Simulations were carried out for the period of 2001–2016 for forest, shrub, grass, and soybean in Jambi Province using the Community Land Model version 5.0 utilizing CRUNCEP atmospheric data and surface data from Hassler *et al.* (2015). Model output were sensible heat flux (SH) and latent heat flux (LE), net radiation (Rn), NPP, GPP, Plant respiration, soil moisture, soil temperature, and air temperature. Validation were conducted using observation data of Rn and calculated latent heat flux using Penman-Monteith equations:

$$ET_o = \frac{0{,}408\,\Delta R_n + \gamma \dfrac{900}{(T+273)} U_2 (e_s - e_a)}{\Delta + \gamma (1 + 0{,}34 U_2)}$$

where ET_0 is potential evaporation, Rn is net radiaton (MJ/m²), T is air temperature (°C), U_2 is wind velocity at 2m above ground (m/s), e_s is saturation vapour pressure (kPa), e_a is actual vapour pressure (kPa), Δ slope curve between vapour pressure and air temperature (kPa/°C), and is psychrometric constant (kPa/°C). ETc was calculated as followed:

ETc = t ,
where LE is latent heat,
L is energy for evaporation,
and t is time step.

The coupling strength index CS_L is calculated as followed: $CS_L = corr(SM,LH)\sigma_{LH}$ where SM is the soil moisture at a depth of 10 cm, LH is latent heat, *corr* is the Pearson correlation coefficient and σ is the standard deviation.

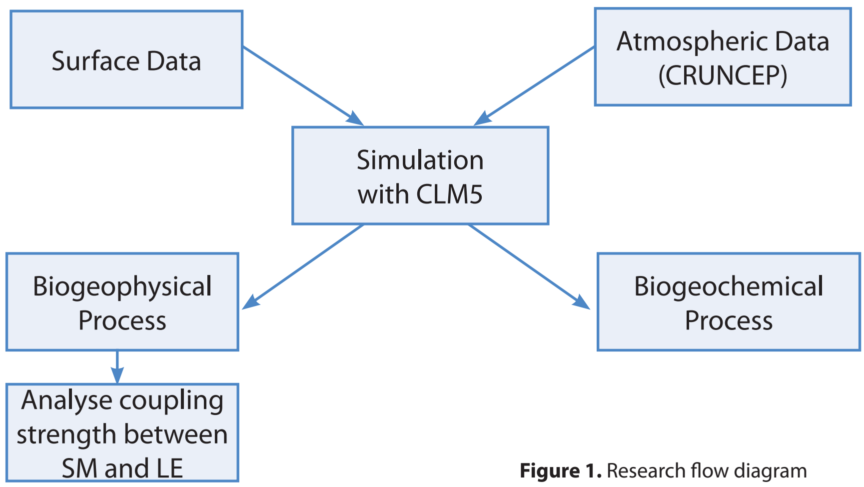

Figure 1. Research flow diagram

Results

Partition of surface energy balance from forest, shrub, grass, and soybean (Figure 2, above). All types of land use showed high utilization of energy for latent heat fluxes LE, indicating adequate availability of water in the region. During the 2015 El Nino, sensible heat fluxes (SH) became dominant. Forest cover had changed into other land uses with decreased latent heat fluxes and increased sensible heat fluxes especially during the strong El Nino (Figure 2b, bottom). When forests change into shrubs, grass, and soybean, albedo increases and surface roughness decreases, hence affecting net radiation and heat transfer respectively.

Forests which have changed into shrubs, grasses, and soybeans have decreased primary production (Figure 3a) especially during a strong El Nino (Figure 3b). During a strong El Nino, all land cover decrease carbon absorption due to water stress with forests maintaining higher carbon uptake due to its higher resilience for drought.

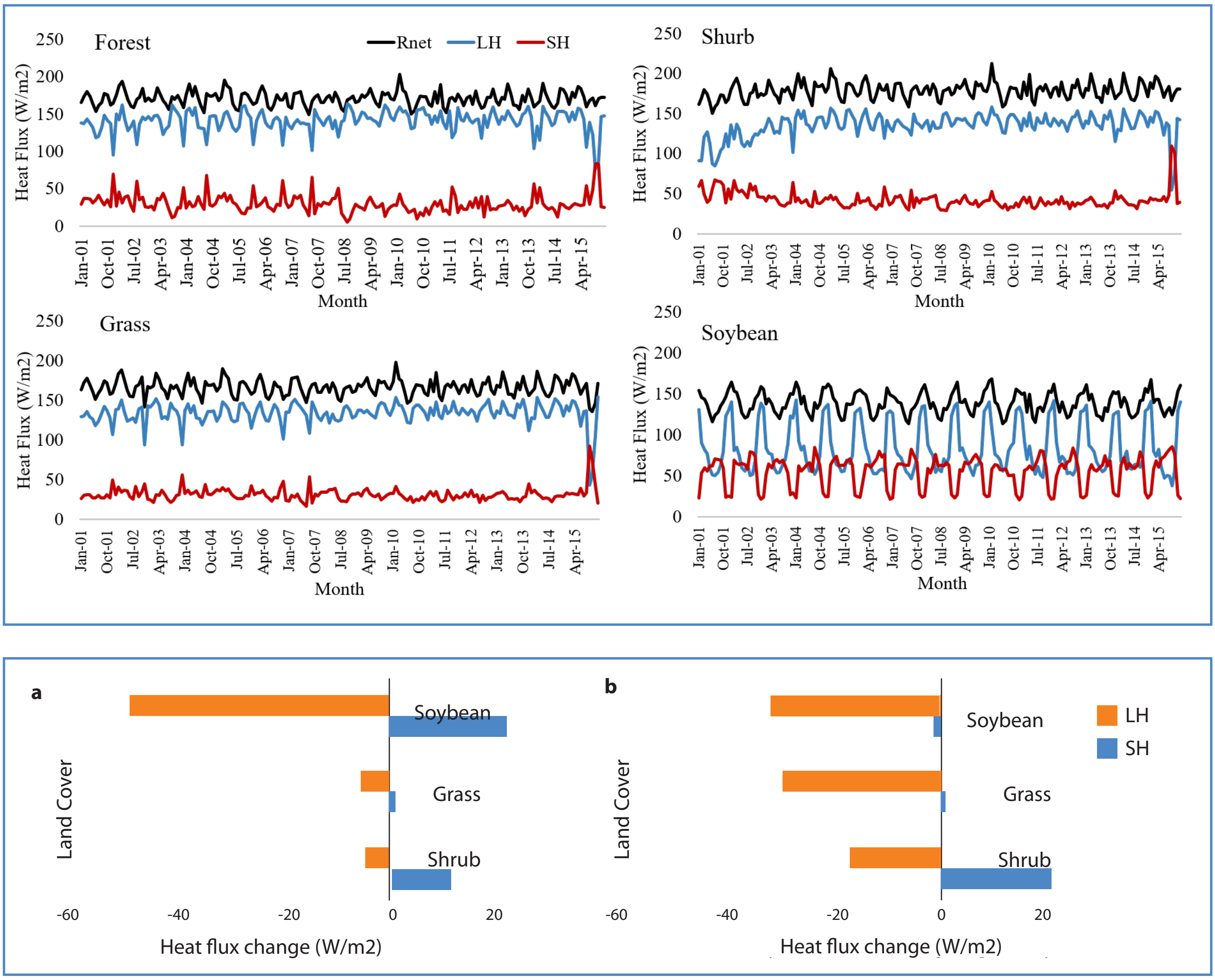

Figure 2. Monthly time series of sensible (SH) and latent heat (LH) fluxes of forest, shrub, grass, and soybean land use types, averaged for the period 2001-2016 (above) and surface heat fluxes changes from forest to shrub, grass, and soybean 2001-2015 (a) and September-October 2015 (b) (bottom).

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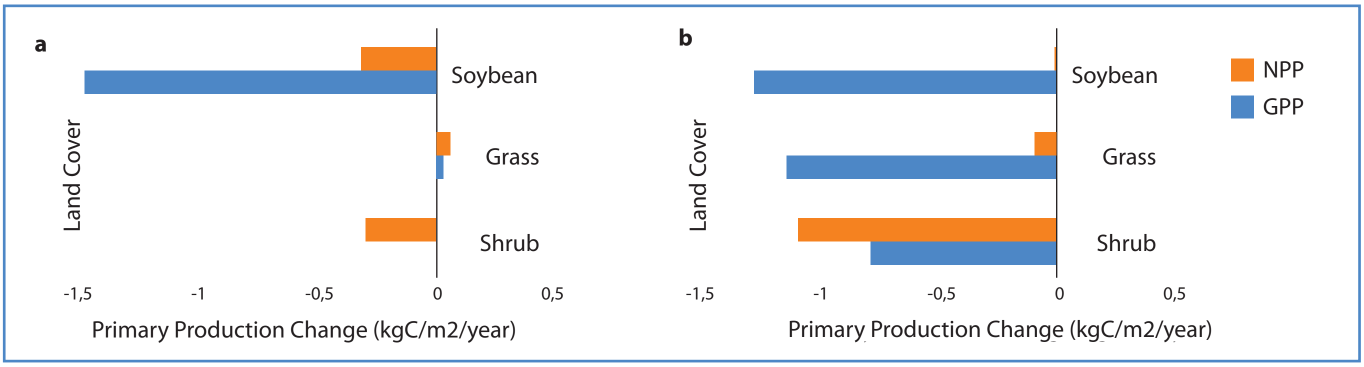

Figure 3. Gross Primary and Net Primary production change from forest to shrub, grass, and soybean for the period 2001–2015 (a) and for September-October 2015 (b)

The connection between land surface to atmosphere consists of two segments, *i.e.* terrestrial and atmospheric segments (Chen and Dirmeyer 2017; Williams *et al*. 2016)this study examines the sensitivity of afternoon atmospheric conditions to morning land surface states and fluxes that are altered by land-cover changes before and since 1850. The deforestation in the eastern United States prior to 1850 leads to increased latent but decreased sensible heat flux during the morning and a reduction in afternoon precipitation over the southern regions of the U.S. East Coast. The agricultural expansion over the Great Plains since preindustrial times shows similar effects on surface fluxes but results in a significant widespread increase in precipitation over the crop area. The coupling metrics exhibit a strong positive soil moisture–precipitation relationship over the Great Plains. Impacts of land-cover change on precipitation manifest through changes in rainfall frequenc...”,”author”:[{“dropping-particle”:””,”family”:”Chen”,”given”:”Liang”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””},{“dropping-particle”:””,”family”:”Dirmeyer”,”given”:”Paul A.”,”non-dropping-particle”:””,”parse-names”:false,”suffix”:””}],”container-title”:”Journal of Climate”,”id”:”ITEM-1”,”issue”:”6”,”issued”:{“date-parts”:[[“2017”]]},”page”:”2121-2140”,”title”:”Impacts of land-use/land-cover change on afternoon precipitation over North America”,”type”:”article-journal”,”volume”:”30”},”uris”:[“http://www.mendeley.com/documents/?uuid=7dee0b08-d142-4935-926f-b9d49d69dc33”]},{“id”:”ITEM-2”,”itemData”:{“DOI”:”10.1002/2016JD025223”,”ISSN”:”21562202”,”abstract”:”Abstract Biases in land-atmosphere coupling in climate models can contribute to climate prediction biases, but land models are rarely evaluated in the context of this coupling. We tested land-atmosphere coupling and explored effects of land surface parameterizations on climate prediction in a single-column version of the National Center for Atmospheric Research Community Earth System Model (CESM1.2.2. We focus on the terrestrial segment (characterized by the correlation between variations in soil moisture and latent heat flux), while the atmospheric segment itself is characterized by the correlation between latent heat flux and precipitation or atmosphere boundary layer height. Coupling strength between soil moisture and latent heat fluxes were positive in all types of land use, indicating that wet soil increases latent heat fluxes (LE), *vice versa*.
Simulated output data of CLM5.0, Rn and LE, correlated significantly with measured/calculated observation data (Figure 4), with $R^2 = 0.8$ and 0.7 respectively.

Table 1. Coupling strength, CS_L , between soil moisture and latent heat fluxes, LE

No	Land Cover	CS_L
1	Forest	19.54
2	Shrub	32.82
3	Grass	35.19
4	Soybean	20.92

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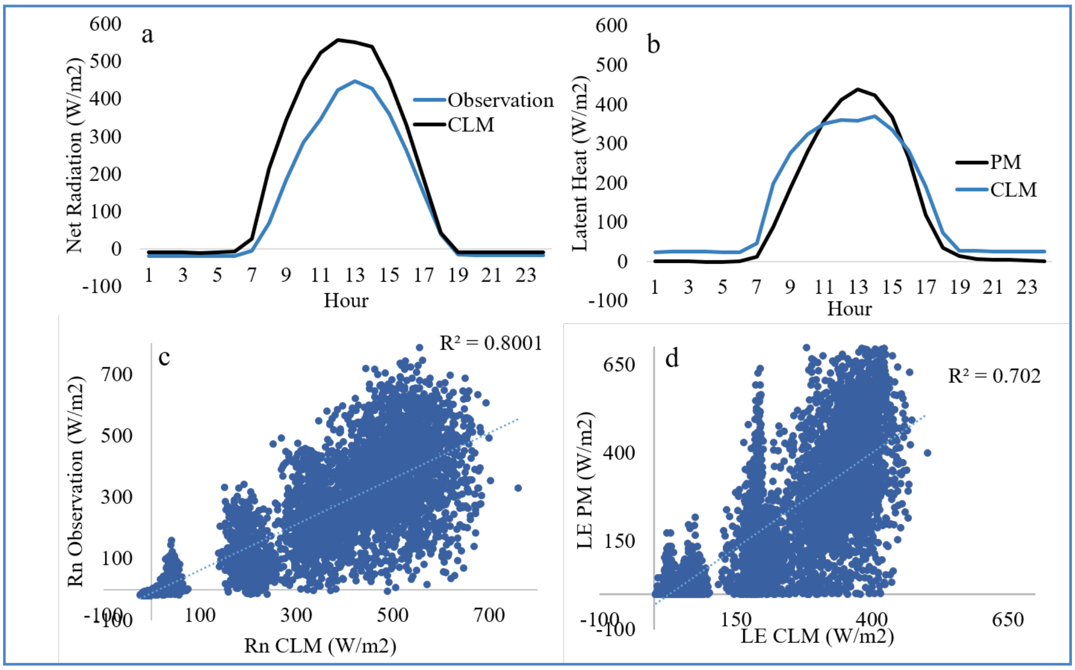

Figure 4.
Validation for net radiation Rn and Latent Heat Fluxes LE output from CLM 5.0 using observation data from the Forest plot sites and calculated LE using Penman Monteith.

Conclusion

Changes in land use alter surface heat fluxes and carbon fluxes. A change of land use from forest to shrub, grass, and soybean decrease latent heat flux and increase sensible heat flux. It modifies carbon absorption. Coupling strength between soil moisture and latent heat flux in all land cover is positive and high. It indicates that land surface has a high impact on surface energy balance.

CRC 990 Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems (Sumatra, Indonesia)

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