POTENTIAL OF FOREST BIOMASS ESTIMATION WITH TOPOGRAPHIC VARIABLES GENERATED FROM SRTM DATA

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ABSTRACT: Estimation of above ground biomass of tropical forests is a very challenging research topic. We explore the potential of topographic variables in estimating the biomass of logged over forest in Sabah, the Malaysian part of Borneo. Various topographic variables were generated from 30m SRTM Digital Elevation Model (DEM) data. Field data were collected at Tangkulap Forest Reserve. Several topographic variables were correlated with the biomass. We then employed multiple linear regression for estimating the biomass. The results show that topographic variables are potentially useful in estimating the biomass of logged over forest. It suggests that the logging intensity has been influenced by the topography of the study area. As the SRTM DEM is a globally consistent data, it should be used for exploring the relationship between forest biomass and topography elsewhere.

1.0 INTRODUCTION

Deforestation is one of the major contributors to the green house gas emission. According to IPCC (2007), deforestation has lead to about 17-20% of global anthropogenic green house gases (GHG) emission which consider as the third largest GHG contributor. The attention of worldwide deforestation focus particularly in tropical forest of South East Asia. Deforestation & forest degradation has been identified in the tropics has been identify as the major source of GHG emission (Fearnside 2000; Laurance and Peres 2006).

Forest biomass can be estimated by using satellite remote sensing data. The notable popular choices of satellite data are Landsat, Spot and Aster. Many research has been done to estimate the forest biomass with these remotely sensed data by correlating the spectral reflectance value or vegetation indices to the field measure biomass. However, due the limitation of spatial and spectral resolutions, the biomass estimation may not be accurate (Lu, 2005; Goetz *et al*., 2009). Some study has used GIS based related environmental factors for biomass estimation. Slik et al (2010) uses environment factors such as elevation, climates and soil variables for estimating forest biomass of Borneo. The result indicated soil fertility has a significant influence on the distribution of above ground biomass (AGB) in Borneo. However, the coarse resolution estimate provides limited practical use to forest management. For this reason, we emphasize the use of medium resolution in analyzing distribution of tropical forest biomass.

Terrain condition may affects the intensity of humans disturbance toward the natural resources (Edge and Marcum, 1991).

Topography is an important factor that limits vegetation growth and restricts human disturbance. SRTM DEM 30m resolution were use to generate topographic indices in GIS environment. We examine the relations of topographic with biomass estimation. This paper serves as a preliminary study to examine the possibility of using topographic indices in estimation of biomass of logged over forest in Sabah, Malaysia.

2.0 MATERIAL AND METHODS

2.1 Study Area

Tangkulap forest reserve is a Class II or commercial forest reserve located in the central part of Sabah, Malaysia (Figure 1). The forest reserve has been harvested by conventional logging since 1970s (Sabah Forestry Department, 2005). The logging continuously and stopped in 2001 following the Sabah's government policy that suspend all conventional logging activities in degraded forest reserve. There has been no logging since 2001. In Tangkulap, the annual average rainfall is 3,000mm. The natural vegetation of the area is predominantly by lowland mixed dipterocarp species. (Sabah Forestry Department, 2006)

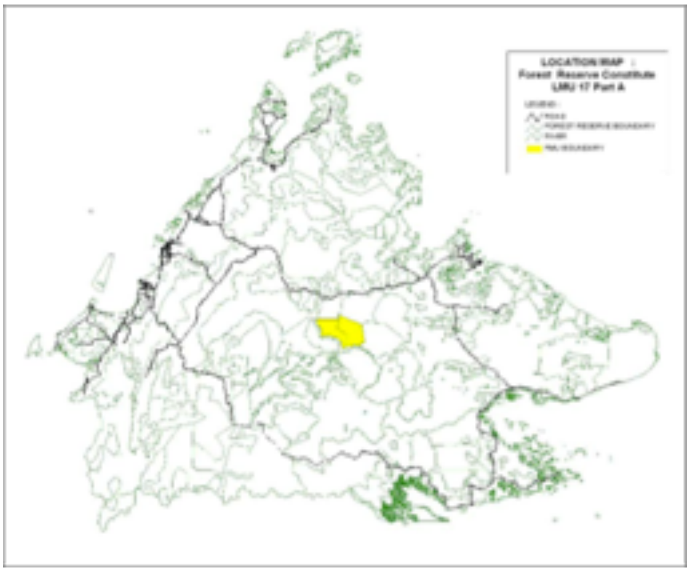

Figure 1. Tangkulap Forest Reserve, Sabah, Malaysia.

2.2 Field work, SRTM DEM and topographical indices

The work flow of this study is shown in figure 2. We collected 20 circular plots with 30m diameter in October 2010 and January 2011 at Tangkulap Forest Reserve. Trees with DBH > 10 cm is measured for tree height and DBH for calculating above ground biomass using allometric equation (Brown, 1997).

The 30m SRTM data was processed in SAGA GIS for calculating the topography indices. 15 topographic indices were generated from the SRTM DEM. The generated indices were then correlated with the biomass data. Multiple regression analysis was employed to determining a statistical model of biomass.

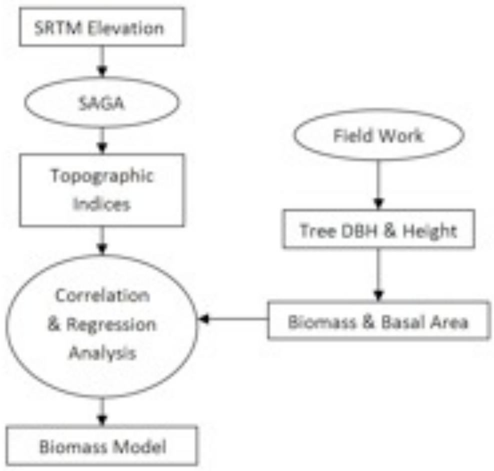

Figure 2. The biomass estimation with topological indices.

3.0 RESULTS AND DISCUSSION

The topography indices generated from SAGA's terrain analysis modules included slope, aspect, curvature, plan curvature, profile curvature, convergence index, catchment area, wetness index, LS-Factor, catchment slope, modified catchment area, SAGA wetness index, terrain ruggedness index, gradient and gradient difference. Above ground biomass is highly correlated with basal area (Figure 3). However, it does not significantly correlates with topographic indices. Basal area is the only field measurement with significant correlation to topographic indices, therefore it is the only parameter to explain the effect of topographic factor in biomass distribution. Result of Pearson correlation analysis shows modified catchment area (MCA) has the highest negative correlation with basal area, R= -0.58, P < 0.005 (Figure 3). Furthermore, basal area has weak correlation with elevation, slope, wetness index and terrain ruggedness. The multiple regression analysis has result a linear model with an adjusted R^2= 0.61. The combination of MCA and terrain ruggedness index (TRI) were the significant predictor of basal area in Tangkulap forest reserve.

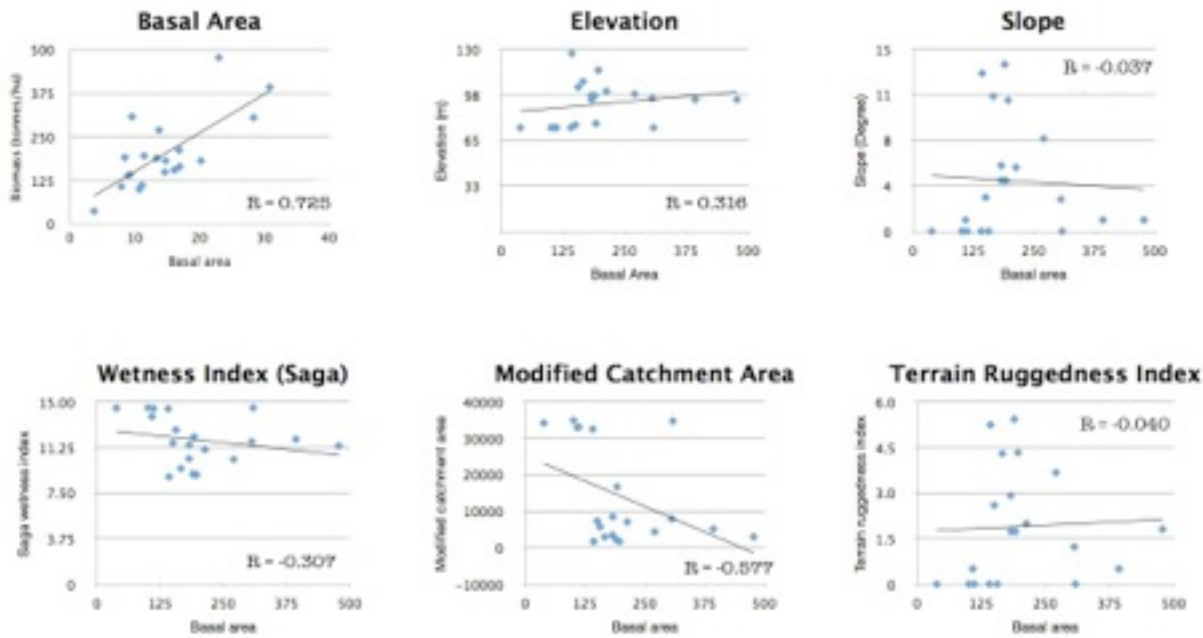

Figure 3. Pearson correlation of (a) biomass and basal area, (b) elevation and basal area, (c) slope and basal area, (d) SAGA wetness index and basal area (e) modified catchment area and basal area, (f) terrain ruggedness index and basal area.

The output of MCA and TRI is showed in Figure 4. Since the study area is located on a logged over forest, the regression model between topography indices and biomass can be used to infer the logging pattern of the past.

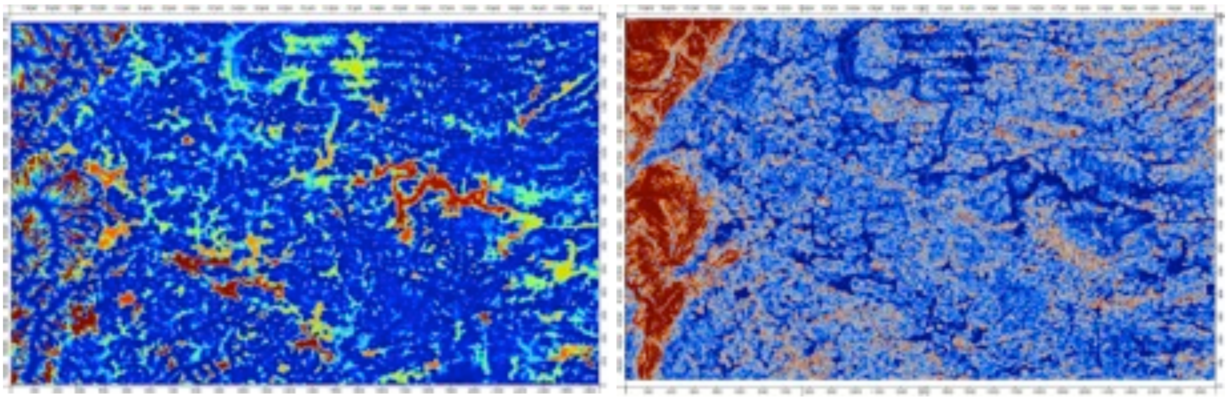

Figure 4. Modified catchment index (Left) and Terrain ruggedness index (Right)

MCA and TRI was calculated based on a 3x3 moving windows across the DEM raster. The detail calculation of TRI is documented in the literature (Riley *et al*., 1999). TRI is derived based on the sum of difference elevation between the center pixel and the neighboring pixel in a 3x3 window. In the reality, TRI reflects the uneven terrain which may limit the logging activities.

The parameterisation of runoff is often based on catchment area calculation for each pixels. Several methods of catchment area calculation can be found in the literature (Conrad, 1990). MCA is modified from the calculation of conventional specific catchment area. Specific catchment area is the total upslope area entering a grid element calculated using the analysis of flow pathways. The difference of MCA is it does not treat the flow as a thin film as done in the calculation of catchment areas in conventional algorithms, as a result it assign a more realistic, higher potential soil wetness. Our results indicated high value of MCA has lower biomass.

Higher the MCA value indicates higher soil nutrient carried by runoff and soil erosion according to gradient.

Due to the limitation of accessible road, our field data has very little variation of terrain. However, our results showed significant difference of biomass distribution over a small variance of topography conditions. Hence, increasing sampling over a greater topography variance may significantly improve the result. and thus provide more valuable informations of past logging intensity in the regenerating forest.

Further examination of the field data, we observed most of the biomass is contributed by high tree numbers. During the field measurement in the end of year 2010 and early 2011, the majority of surveyed trees have DBH less than 20cm (Figure 5). These small trees have regenerated from very intensive logging in the past. The negative correlation between MCA and biomass suggests high biomass areas are found in lower MCA areas. We suspect due to the initial small tree size and difficulties of logging in these rugged terrains, these areas were not heavily logged in the past and undisturbed growing since 2001.

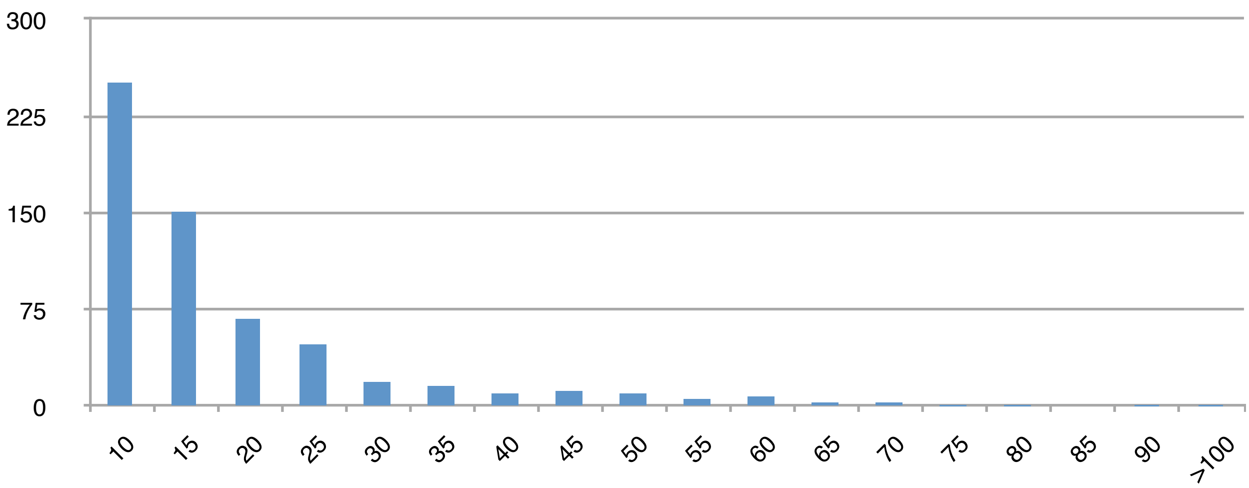

Figure 5. Tree count over DBH in the 20 surveyed plots.

4.0 CONCLUSION

Topography has been known as a factor that influence logging intensity, 15 topography indices were generated from SRTM DEM in SAGA GIS. The multiple linear regression model of MCA and TRI has predicted biomass in the logged over forest. The results suggested the logging operation had been limited in rugged terrain, hence the biomass is higher in the rugged terrain area. We have identified the MCA and TRI as topology factors that are useful in improving biomass estimation in a logged over tropical forest.

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