Comparative study of forest structure between plateau and valley bottom in a central Amazonian forest

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Abstract: Forest structure was compared between plateau and valley bottom in a primary forest namely *terra-firme* in the central Amazon. Three study plots (60 m × 60 m) were established in each topographic type. Stem diameter at breast height (*DBH*) were measured for all trees having *DBH* > 10 cm. The *DBH* were also measured for smaller trees (5 cm < *DBH* < 10 cm) within a partial area (20 m × 60 m) of each plot. The *DBH* – tree height (*H*) relationships were investigated for each topographic type. Frequency distribution of *DBH* was well approximated by a negative exponential function for each topographic type. The exponential functions differed significantly between the two topographic types and suggested the tree density was higher in plateau than in valley bottom. The cumulative basal area was lower at valley bottom than at plateau though large trees (*DBH* > 10 cm) showed an insignificant difference between the two topographic types. The *DBH* – *H* relationship differed significantly between the two topographic types and suggested that the asymptotic *H* was higher in plateau than in valley bottom. The low tree density, cumulative basal area and potential tree height at valley bottom would be partially explained by the stressful environment, such as poor nutrient and waterlogging conditions, at valley bottom.

Key words: Frequency distribution of *DBH,* Potential tree height, Topography

I Introduction

Estimation of biomass in the Amazonian forest is one of the most important issues for evaluating the global carbon dynamics since the Amazonian forest occupies a large portion of the carbon stocks among the terrestrial ecosystems. The main forest type of the Amazonian forest is called as *terra-firme* characterized mainly by a series of plateau and valley bottom. Although it has been known that the forest structure of *terra-firme* depends on soil types influenced by altitude (*2*), the difference in the forest structure between plateau and valley bottom has not been fully revealed.

The present study compared the forest structures at plateau and valley bottom in a central Amazonian forest on the basis of a field study. In the study site, frequency distribution of stem diameter at breast height (*DBH*) was investigated for each topographic type. The *DBH* – tree height (*H*) relationships were also compared between the two topographic types.

II Materials and methods

1 Study site

The present study site locates at ZF-2 Experimental forest of the National Institute for Research in the Amazon (INPA) near Manaus, Brazil. Three quadrates (60 m × 60 m) were established with 60 m intervals between the quadrates at each of plateau and valley bottom. The distance between the plateau and valley bottom sites was more than 340 m. The plateau and valley bottom were characterized by clayey and sandy soil types, respectively (*4*).

2. Tree census

The *DBH* was measured for all tree individuals having *DBH* > 10 cm with identifying common names. In addition, *DBH* was also measured for smaller trees (5 cm < *DBH* < 10 cm) in sub-plots (20 m × 60 m) set within each quadrate.

The *DBH* – *H* relationships were also investigated by randomly sampling 36 and 31 trees from plateau and valley bottom sites, respectively. The *H* was measured using a laser rangefinder (TruPulse 220, Laser Technology, Inc., USA).

3. Models and statistics

The frequency distribution of *DBH* ($\phi(DBH)$) was approximated by the following exponential function:

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$$\phi(DBH) = a\exp(bDBH) \quad (1)$$

where a and b are coefficients.

The $DBH - H$ relationship was fitted to the following hyperbolic function (cf. (*5*)):

$$H = \left[\frac{1}{gDBH} + \frac{1}{h_{\max}}\right]^{-1} \quad (2)$$

where g and h are coefficients.

To examine the differences in Eqs. (1) or (2) between the two sites, one-way ANOVA was carried out on the basis of the residual sum of squares (RSS) when the pooled data were regressed and the sum of RSS when data for each site were regressed separately (*1*).

All nonlinear regression analyses were performed using KaleidaGraph (Synergy Software, USA).

III Results

In total, 1760 individuals were counted with 227 common names though 18 tree individuals were not identified. Relative basal area in each common name suggested that top ten tree groups by common names occupied 31 % and 39 % in plateau and valley bottom sites, respectively (Table 1).

Mean tree density of large and small trees were significantly higher at plateau sites than at valley bottom sites (*t*-test, $p = 2.74 \times 10^{-3}$ for large trees and 1.22×10^{-2} for small trees, Table 2). Large trees showed slightly higher cumulative basal area at plateau sites than at valley bottom sites but the difference was insignificant (*t*-test, $p = 0.344$). On the other hand, small trees showed significantly higher cumulative basal area at plateau sites than at valley bottom sites (*t*-test, $p = 1.65 \times 10^{-2}$).

As shown in Fig. 1, *DBH* showed L-shaped frequency distributions in both of plateau and valley bottom sites, and were well approximated by Eq. (1) ($R^2 = 0.983$ for plateau and 0.995 for valley bottom). The coefficients a and b in Eq. (1) were respectively 3096 $ha^{-1}\ cm^{-1}$ and -0.183 cm^{-1} in plateau and 825 $ha^{-1}\ cm^{-1}$ and -0.107 cm^{-1} in valley bottom. The regression curves differed significantly between the two sites (*F*-test, $p = 2.84 \times 10^{-15}$).

The $DBH - H$ relationship was well approximated by Eq. (2) for each site ($R^2 = 0.916$ for plateau and 0.939 for valley bottom, Fig. 2). The coefficients g and $h_{\max}$ in Eq. (2) were respectively 2.31 m cm^{-1} and 43.7 m in plateau and 1.62 m cm^{-1} and 40.8 m in valley bottom. The regression curves differed significantly between the two sites (*F*-test, $p = 5.06 \times 10^{-7}$).

IV Discussion

Frequency distribution of *DBH* differed between plateau and valley bottom sites. In particular, the tree density of smaller trees seemed higher at plateau than at valley bottom (Table 2 and Fig. 1), which implies a possibility that regeneration processes may be relatively limited in the valley bottom compared with that in the plateau. The plateau and valley bottom in the present study site are characterised by clayey (rich nutrient) and sandy (poor nutrient) soils, respectively (*4*), and the valley bottom is seasonally waterlogged. The poor nutrient and waterlogged conditions at the valley bottom can be one of the factors resulting in the differences of the frequency distribution of *DBH*.

The $DBH - H$ relationship suggested that potential tree height was higher at plateau than at valley bottom (Fig. 2), i.e. $h_{\max}$ ($= H|_{DBH\to\infty}$) in Eq. 2 were 43.7 m and 40.8 m at plateau and valley bottom, respectively. The sandy and poor nutrient conditions at valley bottom may reduce the potential height at valley bottom. In addition, the waterlogging also should be considered as one of the candidate factors reducing potential tree height. A previous study (*3*) suggested that canopy height was higher at well-drained sites than at poorly drained sites in an upper Amazonian region.

Thus, the local differences in the frequency distribution of *DBH* and the $DBH - H$ relationships may be partially explained by the environmental differences between plateau and valley bottom. However, the differences in tree composition also should be considered as one of the factors causing the structural differences since dominant tree groups by common name differed between plateau and valley bottom, i.e. only MATAMATA AMARELO and BREU VERMELHO were common to the top ten dominant groups for both of plateau and valley bottom (Table 1).

V Conclusions

The present results suggested that the forest structures differed considerably between plateau and valley bottom. The comparison of frequency distribution of *DBH* between the two topographies, suggested that the regeneration process of tree species would be restricted in the valley bottom sites. The analysis of the $DBH - H$ relationships revealed that the potential tree height was lower at the valley bottom than at the plateau. Those differences in forest structure would be partially explained by stressful conditions, such as poor nutrient and waterlogging, at the valley bottom. In addition, the differences in species composition between sites also may be reflected in the differences in the structural features.

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References

(*1*) AIBA, S., KOHYAMA, T., 1997. Crown architecture and life-history traits of 14 tree species in a warm-temperate rain forest: significance of spatial heterogeneity. J. Ecol. 85, 611-624.

(*2*) CASTILHO, C.V., MANGNUSSON, W.E., ARAUJO, R.N.O., LUIZAO, R.C.C., LUIZAO, F.J., LIMA, A.P., HIGUCHI, N., 2006. Variation in aboveground tree live biomass in a central Amazonian forest: Effects of soil and topography. For. Ecol. Manage 234, 85-96.

(*3*) DUIVENVOODEN, J.F., 1996. Patterns of Tree Species Richness in Rain Forests of the Middle Caqueta Area, Colombia, NW Amazonia. Biotropica 28, 142-158.

(*4*) FERRAZ, J., OHTA, S., SALLES, P.C., 1998. Distribuic¸ão dos Solos ao Longo de Dois Transectos em Floresta Primária ao Norte de INPA, Manaus, AM. Em: HIGUCHI, N., CAMPOS, M.A.A., SAMPAIO, P.T.B., SANTOS, J. (Eds.), Pesquisas Florestais para Conservac¸aõ da Floresta e Reabilitac¸aõ de Á reas Degradadas da Amazônia, pp. 111-143.

(*5*) OGAWA, H., KIRA, T., 1977.Methods of estimating forest biomass. In: SHIDEI, T., KIRA, T. (Eds.), Primary Productivity of Japanese Forests. University of Tokyo Press, Tokyo, pp. 15-25; 35-36.

Table 1. Ten dominant tree groups based on common name in order of rank determined by relative basal area *RB* in plateau and valley bottom sites.

Rank	Common names	*RB* (%)
Plateau site		
1	MATAMATA AMARELO	6.87
2	RIPEIRO VERMELHO	3.57
3	BREU VERMELHO	3.45
4	CAJUI FOLHA MIUDA	3.17
5	TANIMBUCA	3.11
6	CHICLETE BRAVO	2.67
7	PIAOZINHO	2.26
8	ACARIQUARA ROXA	2.13
9	ABIURANA BACURI	2.12
10	ABIURANA ROXA	1.93
Valley bottom site		
1	SERINGARANA	7.88
2	TARUMA BRANCO	6.44
3	CUMARURANA	4.31
4	SAPOTA	3.93
5	CARDEIRO	3.44
6	MUIRAPIRANGA FOLHA MIUDA	2.94
7	MATAMATA AMARELO	2.69
8	TAUARI	2.63
9	BREU VERMELHO	2.60
10	MUIRAPIRANGA FOLHA GRANDE	2.50

Table 2. Mean tree density and cumulative basal area for large (10 cm < *DBH*) and small (5 cm < *DBH* < 10 cm) trees at plateau and valley bottom sites. Values inside parentheses mean standard error.

	Plateau	Valley bottom
Tree density (ha^{-1})		
Large trees	675.9 (16.1)	563.9 (5.6)
Small trees	800.0 (58.3)	377.8 (77.8)
Basal area ($m^2\ ha^{-1}$)		
Large trees	30.39 (0.45)	27.4 (2.74)
Small trees	3.34 (0.22)	1.77 (0.33)

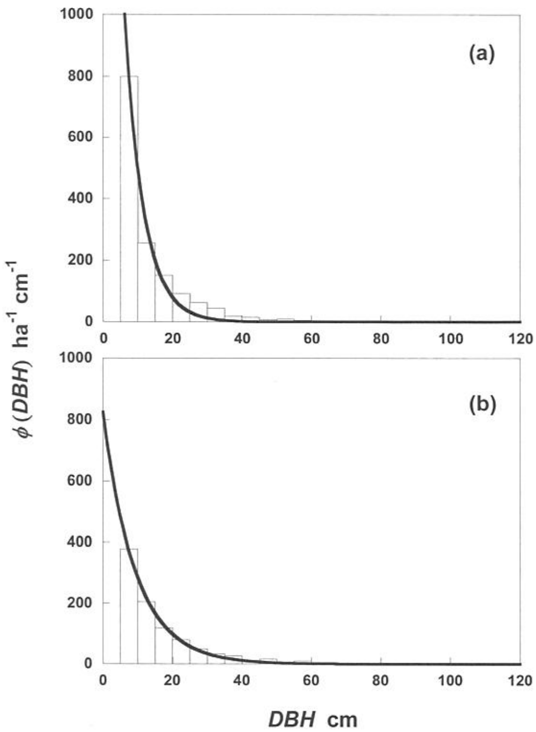

Fig. 1 Frequency distribution of *DBH* (ϕ(*DBH*)) at (a) plateau and (b) valley bottom sites. Each curve is based on Eq. 1.

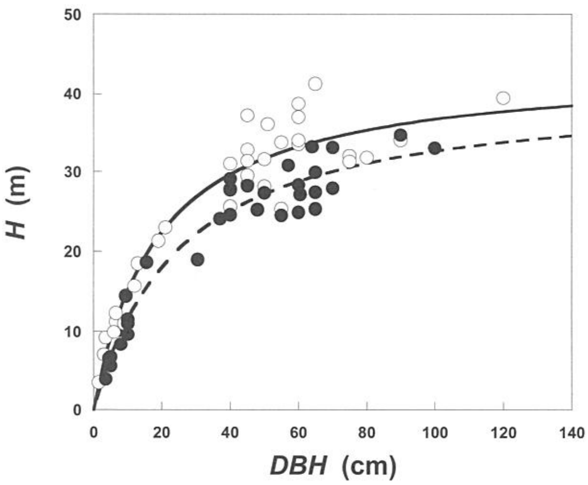

Fig. 2 The *DBH* – *H* relationships at plateau and valley bottom sites. Open circles with solid line and closed circles with dashed line indicate plateau and valley bottom, respectively. Each curve is based on Eq. 2.