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Validation of allometric equations used for estimating aboveground biomass in Indochina

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Abstract: Equations that provide accurate estimates of forest biomass are necessary for monitoring forest degradation. Generic allometric equations have been developed for a range of tree species inhabiting tropical forests, based on collected data. However, these generic equations are unusable in some cases. In this study, we evaluated generic allometric equations for aboveground biomass (AGB) estimation in evergreen and deciduous forests growing in Indochina. In some cases, the AGB estimated for evergreen forests broadly applying existing generic equations was accurate. However, new allometric equations are required for deciduous trees because allometric relationships in existing models do not adequately account for the architecture of deciduous trees.

Keywords: Aboveground biomass estimate, Indochina, Tropical forest

I Introduction

Forests are largest terrestrial carbon store, and they constitute a carbon dioxide sink when a forest is increasing in density or area. Therefore, forest is important for not only preserving biodiversity, but also for reducing greenhouse gases. Forest change has been a focus of constant attention worldwide, especially deforestation and degradation in developing countries.

An estimate of forest biomass is needed for tracking changes in forest degradation. Allometric equations are commonly used for estimating the aboveground biomass (AGB) of standing forest; they relate simple nondestructive measurements, such as diameter at breast height (DBH). A variety of allometric equations has been developed for tropical forests based on data collected from a range of tree species (*1,2,3*). However, these generic equations are unusable in some cases (*4,5,6*). These facts suggest that pre-validating the accuracy of estimate equations for research area is essential.

Three types of tropical forest vegetation are found in Indochina, *i.e.*, evergreen, deciduous, and mixed forests. In this study, we focused on evergreen and deciduous forests to evaluate generic equations for estimating AGB in Indochina.

II Materials and Methods

Our analysis relied on tree-harvest studies by Hozumi *et al.* (1969,(*7*)) and Ogino *et al.* (1967,(*8*)). The data from Hozumi *et al.* were collected from Cambodian evergreens (*Beilschmiedia* spp., *Saraca* spp., and *Garcinia* spp.) (n=86, DBH=2–133 cm), and the data from Ogino *et al.* were collected from Thai evergreens (*Memecylon* spp., *Aglaia* spp., and *Hydnocarpus* spp.) (n=38, DBH=3–33 cm) and deciduous trees (*Shorea* spp. and *Pentace* spp.) (n=25, DBH=2–23 cm). We compared the generic equations of Brown (1997,(*1*)), Chave *et al.*,(2005,(*2*)), and Kiyono *et al.* (2011, in press,(*3*)) (see Table 1 for equations). We defined "error" as the difference between estimated AGB and actual AGB. Wood densities were obtained from data published in IPCC (2003,(*9*)).

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Ⅲ Results and Discussion

1.Evergreen trees The relationship between DBH and error was unclear (Fig. 1a,b), which suggests that the occurrence of error is independent of tree size. Absolute values of maximum and minimum error were large (5,549 kg and -632 kg, respectively, Table 2). These large errors were species-specific (e.g., in *Grewia* spp., *Hopea* spp., *Calophyllum* spp.); most errors, however, were small (25th to 75th percentile: -2.1 kg to 7.3 kg). Thus, the allometric relationships in generic equations were well matched to tropical evergreen tree architecture, except in specific cases.

2.Deciduous trees The errors increased with DBH (Fig.1c). Although the maximum and minimum errors were smaller for deciduous trees than for evergreens (maximum and minimum: 202.39 kg and 0.06 kg, respectively), errors between the 25th and 75th percentiles exceeded those of evergreens. Moreover, all errors were positive and overestimated. Accordingly, allometric relationships of the generic equations are not appropriate for deciduous trees.

3.Comparison of architecture between evergreen and deciduous trees To clarify the difference in the error between evergreen and deciduous trees, we compared the aboveground architecture of both tree types. When comparing both types, evergreens tended to have a larger AGB than deciduous trees for the same DBH (Fig.2). We added to the Cambodian tree data and compared relationship between DBH and tree height (H) (Fig.3), which revealed that evergreens tended to be higher than deciduous trees when comparing the two tree types. These results suggest that the aboveground architecture differs between evergreen and deciduous trees. In addition, the difference in the error implies that the allometric relationships of generic equations fit most of evergreens, but not deciduous trees. Thus, new allometric equations should be developed for deciduous trees.

Ⅲ Conclusion

We recommend that separate allometric equations be developed for evergreen and deciduous trees in Indochina. Species-specific equations would be best for estimating forest AGB because different trees species often differ greatly in architecture. However, because of the huge number of tree species in tropical forests and the enormous effort that would be required to gather appropriate data, development of species-specific equations is unlikely. Therefore, generic equations for evergreen forests offer moderate accuracy and produce estimates with far less labor than approaches involving species-specific sampling. However, insufficient data (especially for large trees) are available for the development of allometric equations applicable to deciduous species. Accurate large-scale estimation of tropical forest AGB will require collection of these data and, in turn, development of these equations.

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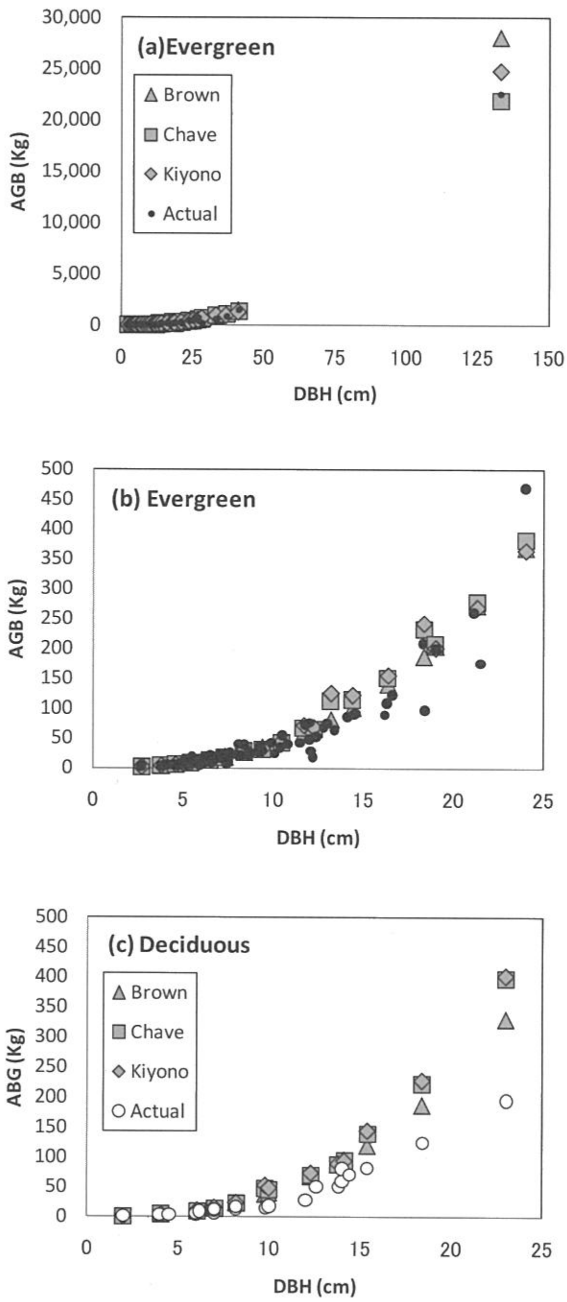

Fig-1. Cross-comparisons of reported allometric relationships between aboveground biomass(AGB) and diameter at breast height (DBH) in (a) evergreens and (c) deciduous trees. (b) A close up of (a). Estimated AGB from Brown(1997)(△), Chave *et al.*,(2005)(□) and Kiyono *et al.*,(in press)(◇).

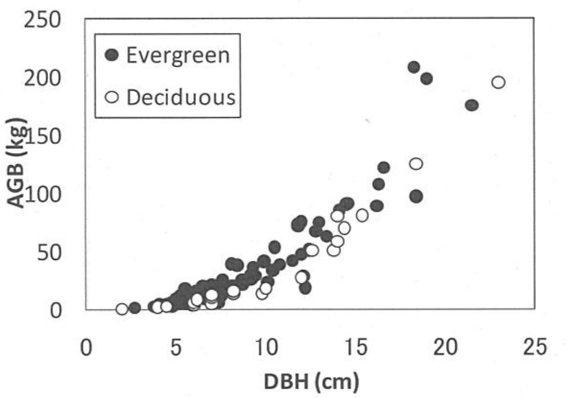

Fig-2. Relationship between diameter at breast height (DBH) and aboveground biomass(AGB).

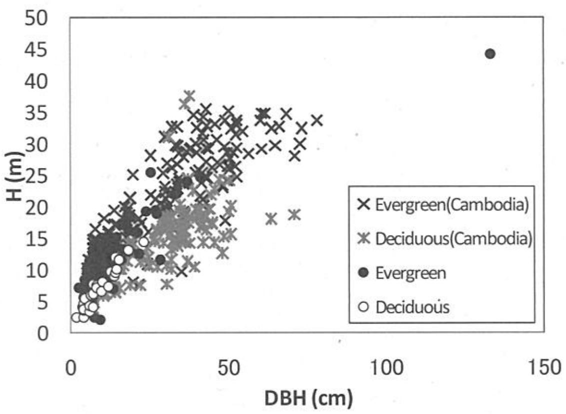

Fig-3. Comparison of the relationships between diameter at breast height (DBH) and height (H) for evergreen and deciduous trees. Circles refer to data from Hozumi *et al.*(1969) and Ogino *et al*(1967). Crosses indicate tree census data from Cambodia.

Table-1. Regression of aboveground biomass (AGB), species used for regressions, and wood density (WD)

Species	Regression	WD	Ref.
Mixed species	$AGB=\exp(-2.134+2.530\times\ln(DBH))$	0.71	Brown(1997)
Mixed species	$AGB=WD\times\exp(-1.562+2.148\times\ln(DBH)+0.207\times(\ln(DBH))^2-0.0281\times(\ln(DBH))^3)$	–	Chave *et al*.(2005)
Mixed species	$AGB=4.27\times ba^{1.27}\times(0.01\times WD)^{1.31}$	–	Kiyono *et al*.(2011.in press)

WD, wood density (t/m^3)

Table-2. Error distribution

Tree type	Equation	Error (Estimated AGB − Actual AGB)				
		Min	25Percentaile	Median	75Percentaile	Max
Evergreen (n=124)	Brown	−120.30	−2.01	0.44	4.63	5549.56
	Chave	−632.62	−2.10	0.07	5.58	559.21
	Kiyono	−235.62	−0.84	1.40	7.03	2175.43
Deciduous (n=25)	Brown	0.14	2.83	10.57	30.48	134.77
	Chave	0.06	1.50	8.52	28.65	202.39
	Kiyono	0.11	2.43	10.13	32.78	205.53