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Aboveground biomass and diversity of woody climber in evergreen forest, southern Vietnam

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ABSTRACT— Woody climbers play an important role in overall plant diversity and carbon storage in a tropical forest. This study aimed at investigating woody climbers in tropical evergreen forests, in southern Vietnam. Forty-four survey plots of 2,500 m^2 each were used for field data collection in four forest types experiencing different disturbances as rich (standing volume/SV>200 m^3/ha), medium (100<SV≤200 m^3/ha, poor (50<SV≤100 m^3/ha), and very poor (10<SV≤50 m^3/ha) forests. Twenty-six woody climbers were recorded with 17 species in rich, 20 in medium, 10 in poor, and 13 in very poor forests. Two species that appeared in poor and very poor forests are missing in rich and medium forests. The diversity Shannon–Weiner index (*H'*) and evenness (*J*) indices are in the order of reducing from rich forest (*H'*=2.37, *J*=0.83) to very poor forest (*H'*=0.92, *J*=0.57). Stem density and aboveground biomass (AGB) of woody climbers were significantly different among four forest types; 876 stems/ha in the rich forest, 1,246 stems/ha in the medium forest, 785 stems/ha in the poor forest, and 1,991 stems/ha in the very poor forest; AGB was 5,570 kg/ha in the rich forest, 9,444 kg/ha in the medium forest, 3,573 kg/ha in the poor forest, and 20,560 kg/ha in the very poor forest. It is concluded that previous disturbances significantly changed the diversity and structure of woody climbers by reducing diversity but increasing stem density and AGB in the forest with higher intensity of disturbance.

KEYWORDS: Carbon storage, Disturbance regime, Forest structure, Host-plant, Life-form.

1. INTRODUCTION

Woody climber (liana) is a prominent life-form and contributes to overall plant diversity occupying an important niche in the tropical forest ecosystem around the world [1- 4]. These woody plants germinate at the ground, root permanently in the soil, then climb host trees to reach the forest canopy [5]. Woody climbers account for 10–45% of total woody stems, up to 35% species diversity [6], [7], and 10–30% total aboveground biomass (AGB) in tropical forests [8]. In a heavily disturbed natural forest, woody climbers can rapidly colonize the open habitats [9]. Woody climbers depend on trees for their growth and compete, hosts, both above and belowground for resources. Therefore, hosts with a heavy load of woody climbers often show decreased growth, increased mortality, and reduced biomass [10], [11]. However, woody climbers also provide a valuable food source for animals [6], increase community stability by physically linking trees together, and provide access for animals [3].

The abundance, diversity, and distribution of woody climbers are affected by several abiotic and biotic factors such as rainfall, seasonality, soil fertility, forest canopy structure, and disturbance regimes [12- 14]. Their abundance and biomass are increasing across tropics as a result of forest fragmentation, natural and anthropogenic disturbances, and global environmental changes [3], [15- 17]. These changes will consequently influence forest structure, composition, and carbon sequestration [18]. Studies on woody climber communities have been mostly neglected in Vietnam, because of their low commercial valuables compared to timber. However, they still contribute a significant role in biomass, carbon storage, plant diversity, and stability in the forest ecosystem. Hence, this study aimed at investigating woody climber AGB, structure, and diversity in tropical evergreen forests, southern Vietnam.

2. MATERIAL AND METHOD

2.1 Study site

The study was conducted at Dong Nai Biosphere Reserve (DNBR), southern Vietnam (Figure 1A). The core zone of DNBR covers an area of 172,502 ha. The study area is characterized as a tropical monsoon climate. There are two distinct seasons with a rainy season during April-November and a dry season during December-March. The site has a mean annual rainfall of 2,450 mm mostly falling during August-September and a mean annual temperature of 25.4°C. Acrisols and Luvisols dominate DNBR. Due to intense rainfall during the rainy season, many small areas in DNBR are periodically inundated for a long time of up to several months, which significantly influences the diversity and growth of plant communities [19].

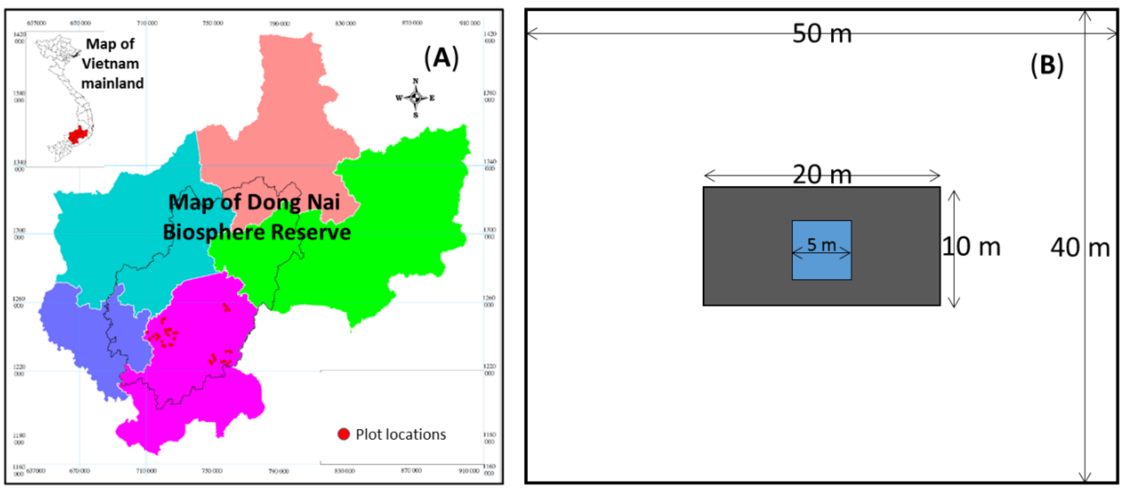

Figure 1. Map of the study area (A) and plot layout (B)

Vegetation in the study site was described as lowland tropical forest dominated by dipterocarps [20], [21]. Most of the forests in DNBR were degraded by selective logging and war during 1961-1996 [22], [23]. Most stems of commercially valuable species (*Anisoptera costata, Dipterocarpus alatus, Dipterocarpus dyeri, Heriteria cochinchinensis, Dipterocarpus costatus, Hopea odorata, Lagerstroemia calyculata, Shorea roxburghii, and Sindora cochinchinensis*) with diameter at breast height larger than 40 cm were cut.

2.2 Data collection

Based on standing volume (SV), forests in the study site were classified to four types as a rich forest with SV > 200 m^3/ha, medium forest with 100 < SV ≤ 200 m^3/ha, poor forest with 50 < SV ≤ 100 m^3/ha, and very poor forest with 10 < SV ≤ 50 m^3/ha. In each forest type, a number of plots were established for data collection (Table 1). The position for the setting plot was selected typically by using a forest cover map.

The main plot of 2.000 m^2 (50 m × 20 m) was used (Figure 1B). In the main plot, all woody climbers with DBH (diameter at 1.3 m from the ground) ≥ 10 cm were identified to species level and measured for DBH. In the center of the main plot, a sub-first plot of 200 m^2 (20 m × 10 m) was set up for identifying species and measuring DBH of all woody climbers with DBH > 5 cm and < 10 cm. In the central of sub-first plot, a sub-second plot of 25 m^2 (5 m × 5 m) was set up for identifying species and measuring DBH of all woody climbers with DBH ≤ 5 cm.

2.3 Data analysis

2.3.1 Estimation

Species diversity was estimated by Shannon – Weiner index (H') [24] and Evenness index (J) [25]. These indices were calculated by Eq. (1) and Eq. (2).

$$H' = -\sum_{i=1}^{s} p_i \bullet \ln p_i \qquad (1),$$

$$J = \frac{H'}{\ln(s)} \qquad (2),$$

where, s is the number of species in the plot and p_i is the proportion of individuals belonging to the i^{th} species. Dry AGB of each woody climber [26] was estimated by Eq. (3).

$$AGB = \exp[-1.347+2.391\bullet Ln\,(DBH)] \quad (3),$$

where, DBH is the diameter at 1.3 m from ground in centimeter and AGB is dry aboveground biomass in kilogram.

Stand parameters including diversity indices, AGB, mean DBH, basal area, stem density were separately calculated for each survey plot among four forest types.

2.3.2 Statistical Analysis

The difference in each concerned parameter among four forest types was assessed by univariate analysis of variance (ANOVA) and post-hoc test. All analyses were conducted using SAS 9.2 at $p = 0.05$ (SAS Institute Inc., Cary, NC, USA).

3. RESULTS

Twenty-six species belonging to 16 families were recorded in 44 survey plots. Of which, 17 species appeared in the rich forest, 20 species in the medium forest, 10 species in the poor forest, and 13 species in the very poor forest (Table 1). The most abundance species is *Bauhinia cardinalis* with 34 stems in very poor forest and 14 stems in the poor forest. Nine species appear in only one forest type, 6 species in two forest types, 3 species in three forest types, and 7 species appear in all four forest types. Two species (*Tetrastigma quadrangulum* and *Acacia comosa*) appearing in poor and very poor forests are missing in rich and medium forests. While 11 species appearing in rich and medium forests are missing in poor and very poor forests.

Table 1. The scientific name of woody climbers and their abundance found in 44 survey plots

No	Scientific	Family	Stem number			
			Rich	***Medium***	***Poor***	***Very poor***
		Plot number	*17*	*14*	*9*	*4*
1	*Abrus precatorius* L	Fabaceae	2	9		
2	*Acacia comosa* Gagnep.	Fabaceae				4
3	*Acacia concinna* (Willd.) DC	Fabaceae		1		13
4	*Ancistrocladus tectorius* (Lour.) Merr.	Ancistrocladaceae	8	7	3	2
5	*Artabotrys intermedius* Hassk.	Annonaceae	5	8		
6	*Bauhinia cardinalis* Pierre ex Gagnep	Fabaceae	4	8	14	34
7	*Caesalpinia minax* Hance	Fabaceae				8
8	*Calycopteris floribunda* (Roxb.) Lamk.	Combretaceae	1	8		1

9	*Combretum latifolium* Blume	Combretaceae	2	1	2	1
10	*Combretum tetralophum* C. B. Clarke.	Combretaceae	1	4		
11	*Dalbergia Candenatensis* (Dennst.) Prain	Fabaceae	7	3		1
12	*Dalbergia curtisii* Prain	Fabaceae	3	2		
13	*Entada pursaetha* DC.	Fabaceae		2	4	
14	*Erycibe cochinchinensis* Gagnep.	Convolvulaceae	1			
15	*Erycibe elliptilimba* Merr. & Chun	Convolvulaceae	1	3		
16	*Gnetum macrostachyum* Hook.f.	Gnetaceae	4	3	1	1
17	*Melodorum fruticosum* Lour.	Annonaceae		5		
18	*Phytocrene oblonga* Wall.	Icacinaceae		1		
19	*Sageretia theezans* (L.) Brongn.	Rhamnaceae		1		
20	*Salacia chinensis* L	Celastraceae		2		
21	*Sargentodoxa cuneata* (Oliv.) Rehd. & Wils	Sargentodoxaceae	2	6	3	5
22	*Sphenodesme pentandra* (Roxb.) Jack	Verbenaceae	21	6	6	3
23	*Strychnos ignatii* Bergius	Loganiaceae	5	4	1	1
24	*Tetrastigma quadrangulum* Gagnep. & Craib.	Vitaceae			1	
25	*Uncaria acida* (Hunt.) Roxb.	Rubiaceae	2			
26	*Uvaria microcarpa* Champ. ex Benth.	Annonaceae	5		1	1
	Species total		**17**	**20**	**10**	**13**

Stand parameters of all woody stems are shown in Table 2. For stems with DBH of ≥ 10 cm, density is significantly different among four forest types, where the highest density was found in the very poor forest, reducing to the medium forest, and poor and rich forests. The difference of DBH was not different. While the differences in basal area and AGB were significant among four forest types. The largest basal area was found in the very poor forest (0.76 m^2/ha). While, the difference among the three other forest types was not significant, which is around 0.08-0.15 m^2/ha. The highest AGB of 7,797 kg/ha was found in the very poor forest, while in three other forest types AGB was much lower, ranging 728-1,339 kg/ha. Both *H’* and *J* diversity indices, and species number were in order of reducing from rich forest (*H’* = 2.04, *J* = 0.89) to very poor forest (*H’* = 0.092, *J* = 0.57).

For stems with DBH 5 cm > and < 10 cm, the differences of stem density, basal area, and AGB were also significantly different among the four forest types (Table 2). The highest density (350 stems/ha), AGB (9,303 kg/ha), and basal area (1.30 m^2/ha) were found in very poor forest and the lowest density (66 stems/ha), AGB (1,602 kg/ha), and basal area (0.23 m^2/ha) was found in poor forest. Similar to ≥ 10 cm DBH stems, both *H’* and *J* diversity indices, and species number were in order of reducing from rich forest (*H’* = 2.37, *J* = 0.90) to very poor forest (*H’* = 1.35, *J* = 0.84).

For stems with DBH ≤ 5 cm, the difference was found only in stem density, which was highest in the very poor forest (1,600 stems/ha), reducing to the medium forest (1,085 stems/ha), and to rich (779 stems/ha) and poor (711 stems/ha) forests (Table 2). *H’* diversity index was in the order of reducing from rich forest (*H’* = 2.25) to very poor forest (*H’* = 2.07), but *J* diversity index (0.83-0.96) was more or less similar in all four forest types, while species number was in the order of reducing from rich forest (15 species) to very poor forest (9 species).

The total density of woody climbers was 876 stems in the rich forest, 1,246 stems in the medium forest, 785 stems in the poor forest, and 1,991 stems in the very poor forest. While, total AGB was 5,570 kg/ha in rich forest, 9,444 kg/ha in medium forest, 3,573 kg/ha in poor forest, and 20,560 kg/ha in very poor forest.

Table 2. Stand parameters of the woody stem in four different forest types

DBH	Parameter	Forest type			
		Rich	Medium	Poor	Very poor
≥ 10 cm	Density (stems/ha)	6 ±2[a]	11 ±2[b]	8 ±5[ab]	41 ±18[c]
	DBH ±SE (cm)	12.7 ±0.7	12.7 ±0.5	11.7 ±0.3	14.7 ±0.5
	Basal area (m^2/ha)	0.08 ±0.02[a]	0.15 ±0.03[b]	0.10 ±0.06[ab]	0.76 ±0.31[c]
	Species number	10	14	6	4
	H'	2.04	2.34	1.41	0.92
	J	0.89	0.85	0.73	0.57
	AGB (kg/ha)	728.0 ±210.9[a]	1,339.6 ±336.9[b]	883.7 ±569.8[a]	7,797.5 ±3,186.2[c]
5 cm > and < 10 cm	Density (stems/ha)	91 ±23[a]	150 ±37[b]	66 ±49[c]	350 ±192[d]
	DBH ±SE (cm)	6.3 ±0.3	6.4 ±0.2	7.2 ±0.8	6.7 ±0.1
	Basal area (m^2/ha)	0.32 ±0.09[a]	0.49 ±0.12[b]	0.23 ±0.15[a]	1.30 ±0.70[c]
	Species number	14	16	4	5
	H'	2.37	2.57	1.13	1.35
	J	0.90	0.93	0.70	0.84
	AGB (kg/ha)	2,261.1 ±658.3[a]	3,435.5 ±846.2[b]	1,602.9 ±1,068.8[a]	9,303.2 ±5,001.4[c]
≤ 5 cm	Density (stems/ha)	779 ±266[a]	1,085 ±279[b]	711 ±218[a]	1,600 ±432[c]
	DBH ±SE (cm)	2.3 ±0.4	2.8 ±0.2	1.7 ±0.3	2.4 ±0.1
	Basal area (m^2/ha)	0.50 ±0.19	0.85 ±0.30	0.24 ±0.08	0.74 ±0.21
	Species number	15	11	7	9
	H'	2.25	2.30	1.82	2.07
	J	0.83	0.96	0.94	0.94
	AGB (kg/ha)	2,581.1 ±1,022.3	4,669.2 ±1,739.8	1,086.8 ±385.6	3,462.1 ±976.2

Different letters [a, b, c, d,] in a row indicate significant differences of means at p =0.05. AGB is dry aboveground biomass, DBH is stem diameter at 1.3 m from the ground, *H'* is Shannon – Weiner index, *J* is Evenness index.

In poor and very poor forests, the highest stem number belonged to the DBH class of < 2.5 cm. While in rich and medium forests the highest stem number belonged to the DBH class of 2.5-5.0 cm (Figure 2). Poor and very poor forests had the exponential shape of stems/DBH distribution. While rich and medium forests had inverted J shape of stems/DBH distribution. Generally, stems of woody climbers with DBH > 7.0 cm were rarely found in all four forest types.

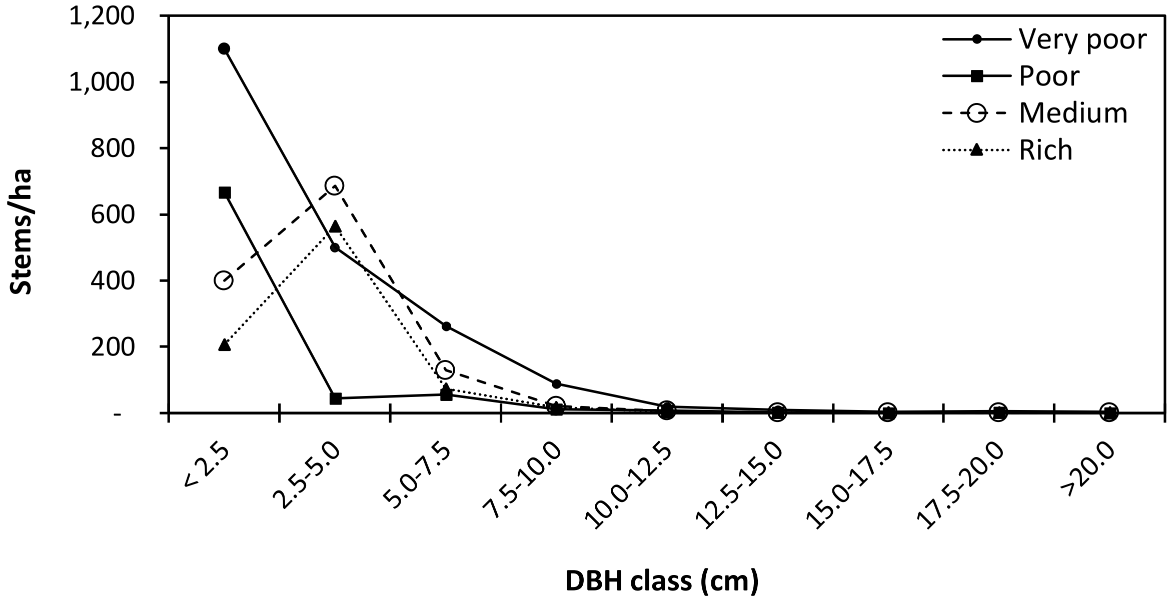

Figure 2. Stem distribution of woody climbers by DBH classes in four forest types

Rich and medium forests had a similar pattern of AGB/DBH distribution (Figure 3) of inverted J shape with a peak at 2.5-5.0 cm DBH class. While poor forest had two peaks of AGB at < 2.5 cm DBH class and 5.0-7.5 cm DBH class. Much difference of AGB/DBH distribution was found in the very poor forest with three peaks at < 2.5 cm DBH class, 5.0-7.5 cm DBH class, and > 20 cm DBH class. Generally, AGB of woody climbers mostly focused on DBH of < 10.0 cm.

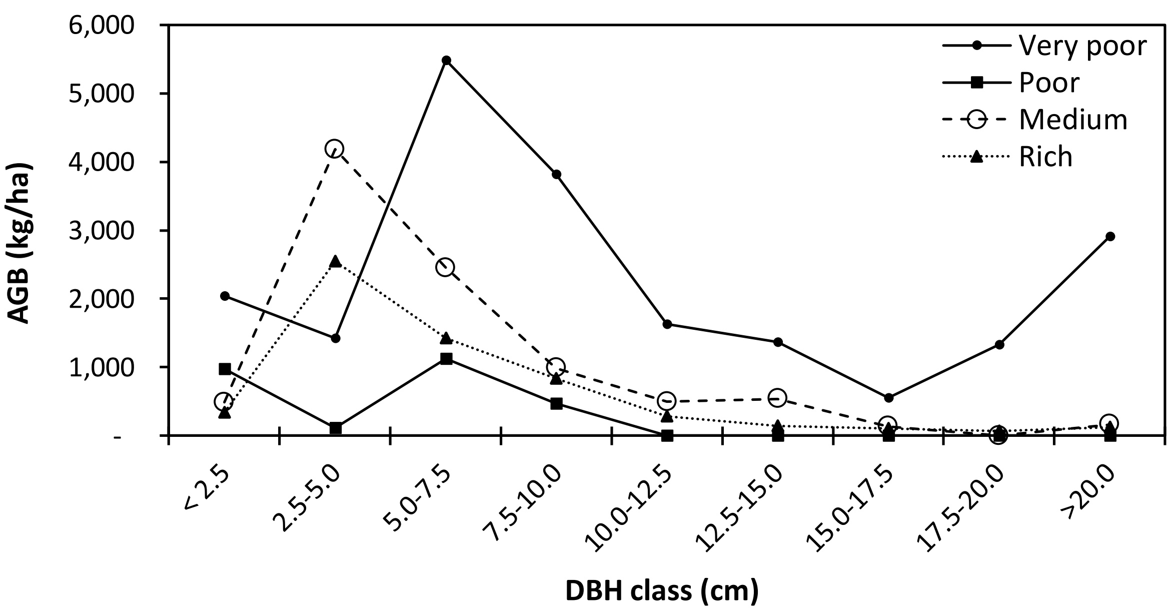

Figure 3. AGB distribution of woody climbers by DBH classes in four forest types

4. DISCUSSION

To promote regeneration and growth of seedlings of commercially valuable species, silvicultural practices [27] were applied mostly in the poor forest as many seedlings were available three. While, it was not allowed to apply rich and medium forests as they are fully protected and fewer seedlings of valuable species were available in the very poor forest, leading to no silvicultural practice application. Such differences in silvicultural application lead to a difference in stem density and AGB among four forest types as the lowest ones were found in the poor forest (785 stems/ha and AGB of 3,573 kg/ha). The lower species number was found in poor and very poor forests compared to much higher ones found in rich and medium forests (Table 1). This could be explained by the difference in living environment as shading level/sunlight penetration [9], [12], [13]. Canopy cover in the poor and the very poor forest was low, the canopy structure was disturbed leading to many open areas, where shade-intolerant and shade-tolerant species cannot survive [28].

In this study, highly disturbed forests as of very poor forest (1,991 stems/ha; 20,560 kg/ha) had much higher stem density and AGB compared to the less disturbed forest as of rich (876 stems/ha; 5,570 kg/ha) and medium (1,246 stems/ha; 9,444 kg/ha) forests. A similar phenomenon was found in other studies [28], [29]. This could be explained by the fact that disturbed forests provide more favorable conditions than less disturbed forests to promote woody climber success [9], [12]. The decrease of diversity indices from rich forests to very poor forest was found in this study (Table 2). A similar pattern was also found in other researches [12], [29]. This indicated that disturbance and change of micro-environment (e.g. light) play a central role in the diversity of woody climbers as most species are shade-tolerant plants. While micro-environment change after disturbance promotes light-demanding woody climbers such as *Tetrastigma quadrangulum* and *Acacia comosa* in the present study (Table 1) leading to their high abundance in the poor and very poor forest while missing in rich and medium forests.

Rich and medium forests had inverted J shape of stems/DBH distribution, which was also found in other less disturbed sites [29]. This indicated that micro-environment is not suitable for many species to germinate and recruit small stems in rich and medium forests. While such condition is suitable for many light-demanding species in poor and very poor forest and therefore stem density of woody climbers was very high in the smallest DBH class (< 2.5 cm DBH class), leading to the exponential shape of stems/DBH distribution (Figure 3 and Figure 4).

5. CONCLUSIONS

Previous human disturbances have significantly impacted stem density, species diversity, and aboveground biomass of woody climbers in evergreen tropical forests, southern Vietnam. Very poor forest with high intensity of human disturbances as selective logging led to high density and AGB of woody climbers but low diversity. Meanwhile, silvicultural practice to promote regeneration and growth of commercially valuable species has led to low density, AGB, and diversity of woody climbers in the poor forest. Less disturbed forests as of rich and medium forests had lower density and AGB of woody climbers but higher diversity both in terms of species number and diversity indices. Therefore, maintaining woody climbers in the tropical forest could promote plant conservation, while still plays an important role in carbon sequestration.

6. ACKNOWLEDGEMENT

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