KEMENTERIAN RISET, TEKNOLOGI DAN PENDIDIKAN TINGGI
UNIVERSITAS UDAYANA
FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
Kampus Bukit Jimbaran Bali - Telp./Fax. (0361) 703137, 701954 Ext. 226

SURAT TUGAS

No : 506/UN14.2.8.I/EP/2018

Yang bertanda tangan dibawah ini, memberikan tugas kepada staf dosen Program Studi Biologi.

Nama	: Prof. Dr. Ir. I Putu Gede Ardhana, M.AgrSc.,SH.
NIP	: 19491102 197603 1 001
Pangkat/Gol	: Pembina Utama Madya / IVd
Unit Kerja	: Jurusan Biologi F. MIPA UNUD

Untuk mengikuti seminar internasional "International Conference on Biodiversity."

Hari/Tanggal	: 10 Desember 2017
Tempat	: Kuta Central Park Hotel

Demikian surat tugas ini dibuat untuk dapat dipergunakan sebagaimana mestinya

Bukit Jimbaran, 22 Januari 2018
Wakil Dekan I,

Drs. I Made Satriya Wibawa,M.Si
NIP. 196605 199210 1 001

Front cover: Musa acuminata Colla
(PHOTO: ICHWARSNUR)

Published quarterly

PRINTED IN INDONESIA

ISSN: 1412-033X

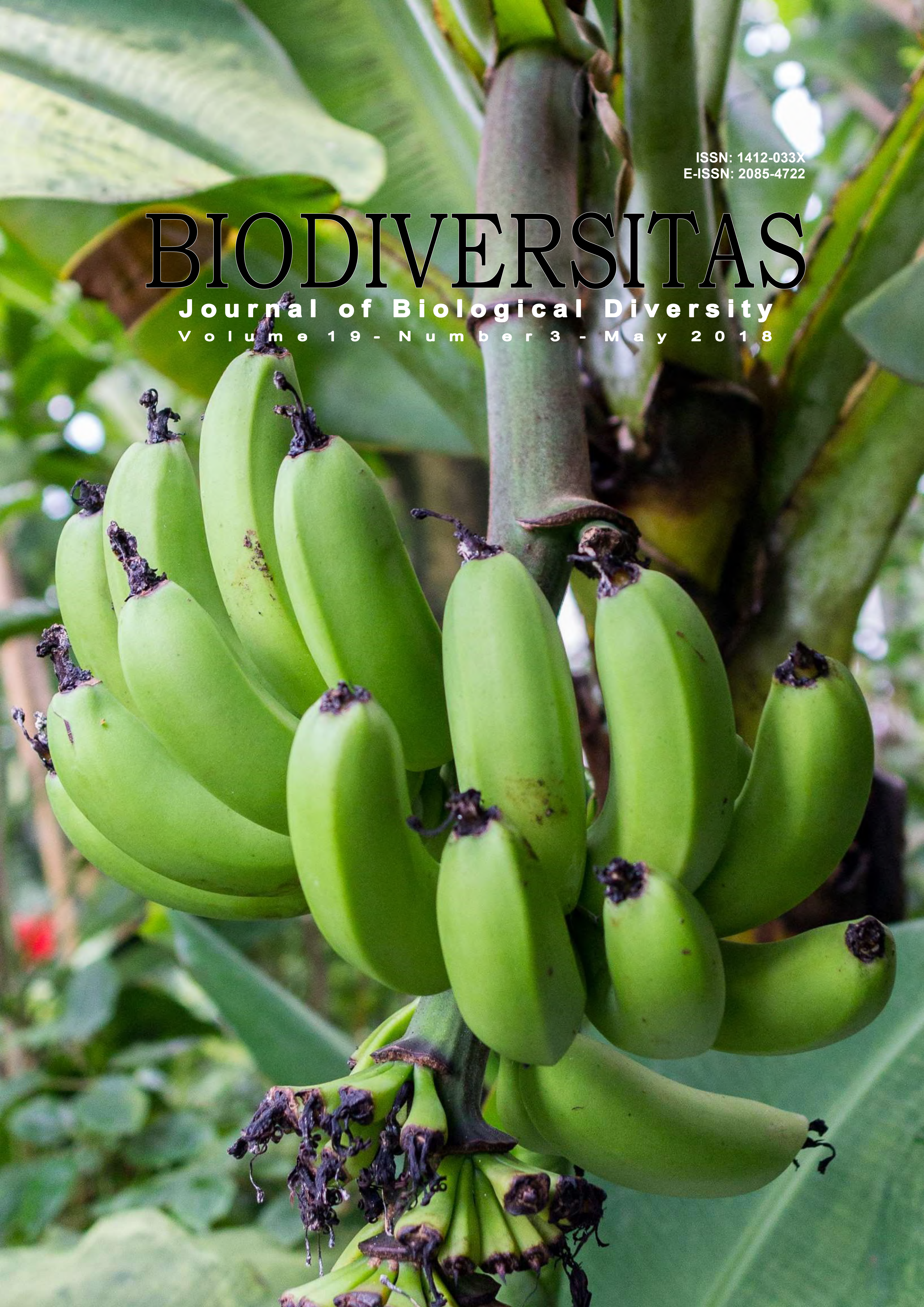
E-ISSN: 2085-4722

ISSN: 1412-033X
E-ISSN: 2085-4722

BIODIVERSITAS

Journal of Biological Diversity

Volume 19 - Number 3 - May 2018



BIODIVERSITAS

Journal of Biological Diversity

Volume 19 – Number 3 – May 2018

ISSN/E-ISSN:
1412-033X (printed edition), 2085-4722 (electronic)

PUBLISHER:
The Society for Indonesian Biodiversity

CO-PUBLISHER:
Department of Biology, Faculty of Mathematics and Natural Sciences, Sebelas Maret University, Surakarta

ADDRESS:
Jl. Ir. Sutami 36A Surakarta 57126. Tel. +62-271-7994097, Tel. & Fax.: +62-271-663375, Email: unsjournals@yahoo.com

ONLINE:
biodiversitas.mipa.uns.ac.id

Society for Indonesia Biodiversity

Sebelas Maret University Surakarta

GUIDANCE FOR AUTHORS

Aims and Scope *Biodiversitas, Journal of Biological Diversity* or abbreviated as *Biodiversitas* encourages submission of manuscripts dealing with all biodiversity aspects of plants, animals and microbes at the level of the gene, species, and ecosystem as well as ethnobiology.

Article types The journal seeks original full-length research papers, reviews, and short communication. Manuscript of original research should be written in no more than 8,000 words (including tables and picture), or proportional with articles in this publication number. Review articles will be accommodated, while, short communication should be written at least 2,000 words, except for pre-study.

Submission The journal only accepts online submission, through open journal system (**https://smujo.id/biodiv/about/submissions**) or email to the editors at **unsjournals@gmail.com**. Submitted manuscripts should be the original works of the author(s). The manuscript must be accompanied by a cover letter containing the article title, the first name and last name of all the authors, a paragraph describing the claimed novelty of the findings versus current knowledge. Submission of a manuscript implies that the submitted work has not been published before (except as part of a thesis or report, or abstract); and is not being considered for publication elsewhere. When a manuscript written by a group, all authors should read and approve the final version of the submitted manuscript and its revision; and agree the submission of manuscripts for this journal. All authors should have made substantial contributions to the concept and design of the research, acquisition of the data and its analysis; drafting of the manuscript and correcting of the revision. All authors must be responsible for the quality, accuracy, and ethics of the work.

Ethics Author(s) must obedient to the law and/or ethics in treating the object of research and pay attention to the legality of material sources and intellectual property rights.

Copyright If and when the manuscript is accepted for publication, the author(s) still hold the copyright and retain publishing rights without restrictions. Authors or others are allowed to multiply article as long as not for commercial purposes. For the new invention, authors are suggested to manage its patent before published.

Open access The journal is committed to free-open access that does not charge readers or their institutions for access. Readers are entitled to read, download, copy, distribute, print, search, or link to the full texts of articles, as long as not for commercial purposes. The license type is CC-BY-NC-SA.

Acceptance The only articles written in English (U.S. English) are accepted for publication. Manuscripts will be reviewed by editors and invited reviewers(double blind review) according to their disciplines. Authors will generally be notified of acceptance, rejection, or need for revision within 1 to 2 months of receipt. The manuscript is rejected if the content does not in line with the journal scope, does not meet the standard quality, inappropriate format, complicated grammar, dishonesty (i.e. plagiarism, duplicate publications, fabrication of data, citations manipulation, etc.), or ignoring correspondence in three months. The primary criteria for publication are scientific quality and biodiversity significance. **Uncorrected proofs** will be sent to the corresponding author by email as *.doc* or *.docx* files for checking and correcting of typographical errors. To avoid delay in publication, corrected proofs should be returned in 7 days. The accepted papers will be published online in a chronological order at any time, but printed in January, April, July and October.

A charge Starting on January 1, 2017, publishing costs waiver is granted to foreign (non-Indonesian) authors who first publish the manuscript in this journal, especially for graduate students from developing countries. However, other authors are charged USD 250 (IDR 3,500,000).

Reprints The sample journal reprint is only available by special request. Additional copies may be purchased when ordering by sending back the uncorrected proofs by email.

Manuscript preparation Manuscript is typed on A4 (210x297 mm^2) paper size, **in a single column**, single space, 10-point (10 pt) Times New Roman font. The margin text is 3 cm from the top, 2 cm from the bottom, and 1.8 cm from the left and right. Smaller lettering size can be applied in presenting table and figure (9 pt). Word processing program or additional software can be used, however, it must be PC compatible and Microsoft Word based (*.doc* or *.rtf*; **not .docx**). **Scientific names** of species (incl. subspecies, variety, etc.) should be written in italic, except for italic sentence. Scientific name (genera, species, author), and cultivar or strain should be mentioned completely for the first time mentioning it in the body text, especially for taxonomic manuscripts. Name of genera can be shortened after first mentioning, except generating confusion. Name of the author can be eliminated after first mentioning. For example, *Rhizopus oryzae* L. UICC 524, hereinafter can be written as *R. oryzae* UICC 524. Using trivial name should be avoided, otherwise generating confusion. **Biochemical and chemical nomenclature** should follow the order of the IUPAC - IUB. For DNA sequence, it is better used Courier New font. Symbols of standard chemical and abbreviation of chemistry name can be applied for common and clear used, for example, completely written butilic hydroxyl toluene (BHT) to be BHT hereinafter. **Metric measurement** use IS denomination, usage other system should follow the value of equivalent with the denomination of IS first mentioning. Abbreviations set of, like g, mg, mL, etc. do not follow by dot. Minus index (m^{-2}, L^{-1}, h^{-1}) suggested to be used, except in things like "per-plant" or "per-plot". **Equation of mathematics** does not always can be written down in one column with text, in that case can be written separately. **Number** one to ten are expressed with words, except if it relates to measurement, while values above them written in number, except in early sentence. The fraction should be expressed in decimal. In the text, it should be used "%" rather than "percent". Avoid expressing ideas with complicated sentence and verbiage, and used efficient and effective sentence.

Title of the article should be written in compact, clear, and informative sentence, preferably not more than 20 words. Name of author(s) should be completely written. **Name and institution** address should also be completely written with street name and number (location), postal code, telephone number, facsimile number, and email address. Manuscript written by a group, author for correspondence along with address is required. First page of the manuscript is used for writing above information.

Abstract should not be more than 200 words. **Keywords** is about five words, covering scientific and local name (if any), research theme, and special methods which used; and sorted from A to Z. All important **abbreviations** must be defined at their first mention. **Running title** is about five words. **Introduction** is about 400-600 words, covering the background and aims of the research. **Materials and Methods** should emphasize on the procedures and data analysis. **Results and Discussion** should be written as a series of connecting sentences, however, for manuscript with long discussion should be divided into subtitles. Thorough discussion represents the causal effect mainly explains for why and how the results of the research were taken place, and do not only re-express the mentioned results in the form of sentences. **Concluding** sentence should be given at the end of the discussion. **Acknowledgments** are expressed in a brief; all sources of institutional, private and corporate financial support for the work must be fully acknowledged, and any potential conflicts of interest are noted.

Figures and Tables of maximum of three pages should be clearly presented. Title of a picture is written down below the picture, while title of a table is written above the table. Colored figures can only be accepted if the information in the manuscript can lose without those images; chart is preferred to use black and white images. Author could consign any picture or photo for the front cover, although it does not print in the manuscript. All images property of others should be mentioned source. **There is no appendix**, all data or data analysis are incorporated into Results and Discussions. For broad data, it can be displayed on the website as a supplement.

References Author-year citations are required. In the text give the authors name followed by the year of publication and arrange from oldest to newest and from A to Z. In citing an article written by two authors, both of them should be mentioned, however, for three and more authors only the first author is mentioned followed by et al., for example: Saharjo and Nurhayati (2006) or (Boonkerd 2003a, b, c; Sugiyarto 2004; El-Bana and Nijs 2005; Balagadde et al. 2008; Webb et al. 2008). Extent citation as shown with word "*cit*" should be avoided. Reference to unpublished data and personal communication should not appear in the list but should be cited in the text only (e.g., Rifai MA 2007, pers. com. (personal communication); Setyawan AD 2007, unpublished data). In the reference list, the references should be listed in an alphabetical order (better, if only 20 for research papers). Names of journals should be abbreviated. Always use the standard abbreviation of a journal's name according to the **ISSN List of Title Word Abbreviations** (www.issn.org/2-22661-LTWA-online.php). The following examples are for guidance.

Journal:

Saharjo BH, Nurhayati AD. 2006. Domination and composition structure change at hemic peat natural regeneration following burning; a case study in Pelalawan, Riau Province. Biodiversitas 7: 154-158.

Book:

Rai MK, Carpinella C. 2006. Naturally Occurring Bioactive Compounds. Elsevier, Amsterdam.

Chapter in book:

Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds) Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th annual symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.) Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

Information from internet:

Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. www.molecularsystemsbiology.com

THIS PAGE INTENTIONALLY LEFT BLANK

BIODIVERSITAS
Volume 19, Number 3, May 2018
Pages: 918-926

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d190322

The distribution of vertical leaves and leaves biomass on ten mangrove species at Ngurah Rai Forest Park, Denpasar, Bali, Indonesia

I PUTU GEDE ARDHANA[1,♥], I M.G.S. RIMBAWAN[2], PUJO NUR CAHYO[2], YUYUN FITRIANI[3], SISKA ROHANI[4]
[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Udayana. Jl. Raya Kampus Unud, Jimbaran, Kuta Selatan, Badung 80361, Bali, Indonesia. Tel./fax +62-361-701954, ♥email: crescentbali@indo.net.id
[2]Climate Change Control and Forest Fire and Land Border of The Region of Java, Bali, and Nusa Tenggara. Jl. Bypass Ngurah Rai Km. 21, Suwung Kauh, Pemogan, Denpasar 80221, Bali, Indonesia
[3]Faculty of Agriculture, Universitas Udayana. Jl. Raya Kampus Unud, Jimbaran, Kuta Selatan, Badung 80361, Bali, Indonesia
[4]Program of Environmental Science, School of Graduates, Universitas Udayana. Jl. P.B. Sudirman, Denpasar 80232, Bali, Indonesia

Manuscript received: 12 December 2017. Revision accepted: 27 April 2018.

Abstract. *Ardhana IPG, Rimbawan IMGS., Cahyo PN, Fitriani Y, Rohani S. 2018. The distribution of vertical leaves and leaves biomass on ten mangrove species at Ngurah Rai Forest Park, Denpasar, Bali, Indonesia. Biodiversitas 19: 918-926.* The distribution of vertical leaves and leaves biomass which forms the mangrove crown divides into three parts, namely the top part, the middle part, and the bottom part. Total amount leaves on any parts are highly variable depending on height of each species. The relationship between the height of tree with the crown thickness depended on total leaves of each crown on each species as well as the relationship between the total leaves biomass of each crown on each species, with the height and volume of tree stems, also has variation on each mangrove species. Author examined the relationship between the photosynthetic organs with non-photosynthetic organs, especially on stems in each species. The high total amount of leaves and large total amount leaves biomass deeply is depended on diameter and growth height which are presented in the form of stem volumes. On the relationship between the photosynthetic organs and non-photosynthetic organs on each mangrove species, also has been examined. The higher total amount of leaves or the total amount of leaves biomass largely depended on the stem volume of mangroves. This indicates that the production of photosynthetic organ either in the form of the total amount of leaves or the total amount of leaves biomass serve to support growth of the stem mangrove trees (height of stem, diameter of stem and volume of stem).

Keywords: Adaptation, multi-layer, mangrove species, vertical leaves and leaves biomass distributions

INTRODUCTION

This study includes a form of adaptation of tree architecture both in the tropics and in the temperate regions. This architectural form is heavily influenced by the sunlight received by the tree crown from the top of the tree to the lowest canopy of the tree. Form of tree architecture adaptation is in the form of monolayer and multilayer. Of the 10 mangrove species exhibit a multilayer adaptive form with different distribution of leaves from the top of the crown, middle and bottom. Meanwhile, if the monolayer form of the number of leaf distribution shows the number of leaves from top to bottom of the crown is uniform because it gets a little sunlight under the shade of tree stands in this study is not found form of monolayer architecture adaptation. The adaptative architecture of trees in tropical forests has been examined in successive (Chazdon 1986; Givnish 1982). The research on adaptative architecture of trees on mangrove forest in tropical does not exist yet, but has done a lot of research on the distribution of carbon stocks, and productivity of mangrove forest (see Camacho et al. 2011; Fatoyinbo and Simard 2013; Sitoe et al. 2014; Taberima et al. 2014; Sahu et al. 2016; Njana et al. 2017). The research on adaptive architecture of tree in the temperate regions has also been done (see Horn 1971; Nicola and Pickets 1983; Ehlesinger and Kenneths 1986; Ardhana et al. 1988). These researchers related with adaptive architecture of trees such as the distribution of leaves pattern, the leaves biomass and the absorption of carbon. The distribution of leaves pattern, leaves biomass, absorption of carbon with growth of the stem are major causes of the highlight of environmental constraints, such as potential total amount leaves at the bottom, middle and top layer of crown to absorb sunlight (Chazdon 1985, 1986). The adaptive architecture of trees has possibility which forms the response of adaptive group of leaves in unit trees (Waller and Steingracher 1986); adaptive photosynthesis (Givnish 1982); the role of carbon balance and the branching pattern in growth of trees (Schulze et al. 1986). Those become major causes of stress for environmental constraint that occurs in the part of crown trees. If overstorey does not have full of sunlight, the growth of crown trees is varied layers such as bottom, middle and top layers.

The effective distribution of leaves or leaves biomass is very important for the survival of living leaves in all species of trees. The distribution and growth of crown structure in overstory and understory trees are commonly subject to various constraints such as limited light condition in the crown trees (Chazdon 1985, 1986; Taberima et al. 2014). The adaptive architecture of trees may form collective response of modular unit in the plants

(Waller and Steingraeber 1986; Taberima et al. 2014) for the common environmental condition of leaves in the layer of crown of overstory species. The research about the distribution of leaves and the leaves biomass are associated with absorption of carbon in the atmosphere at both the photosynthesis (leaves) organs and non-photosynthesis (stems) organs, but for mangrove species, research is rare.

The purpose of this research is to compare the distribution pattern of vertical leaves and leaves biomass on ten mangrove species, and to understand the relationship between the photosynthesis organ and non-photosynthesis organs on each mangrove species.

MATERIALS AND METHODS

This study was carried out in the secondary forest of mangrove as former fishpond farms at Ngurah Rai Forest Park, Denpasar, Bali, Indonesia ($115^0$9'-$115^0$14'E, $8^0$42'-$8^0$49'S) 3.5 km east of Denpasar City. The sphere of temperature ranges from 22^0C-28^0C and annual precipitation are 1,800 mm, with climate type of E (Schmidt Fergusson). A study plot which has size of 20 m x 20 m was used in this Forest Park. The soil conditions are poor as former fishpond farms and the soil profile does not show the developed mineral soil layers (a layer).

The crown of any tree species was divided into three parts of crown layers which are part of top layer, middle and bottom layer. In the plot, the light condition from the sun is state of being open. All species belong to the overstory species, were identified and noted, in order to measure species density. But the leaves distribution on the top layer, middle and bottom layer were different, and most distribution of leaves is part of multi-layer species. But in the bottom crown part, highest total amount leaves were showed, and also the amount of biomass content and carbon became high. Comparison between tree height and crown thickness with the total amount of carbon which absorbed by leaves as photosynthesis organs showed that there was closely relation to any carbon content of non-photosynthesis organs, especially the tree height of stems. In any species, the relation between amounts of leaves with tree height also varied with the value of *r* could be seen in Figure 1, so those were showing the positive relation.

The distribution of leaves, leaves biomass, and any carbon content of leaves were studied for ten dominant overstory species among others *Rhizophora mucronata, R. apiculata, R. stylosa, Bruguiera gymnorrhiza, Ceriops tagal, Sonneratia alba, Avicennia alba, Lumnitzera racemosa, Xylocarpus moluccensis* and *Phempis acidula.* The sum of the sample trees can be seen in Table 1, the sample of every tree species is divided vertically into three parts of layers, namely the top, the middle and the bottom part of layers, and total amount leaves in each part were calculated over the period of June to August 2016.

Biomass of photosynthesis organs and non-photosynthesis organs of ten mangrove species has been calculated. Non-photosynthesis organs were obtained from diameter, tree height and the form value in each stem of sample species were multiplied by the value of 0.7, then calculated the volume of stems with the formula:

$$V = \pi r^2 \text{ x } T \text{ x } 0.7 \text{ (Asy'ari et al. 2012)} \quad (1)$$

Where:
V : Volume
T : Tree height (cm)

While to obtain the wood density of stem, it was used the wood density from the table of Global Wood Density Data Base (Zanne et al. 2009; ITTO 2013), which has The International-Standard. But especially for *P. acidula* species, the formula cannot be found from the global wood density table. Hence to calculate the wood density we used this formula:

$$BJ = BK \text{ (g)}/V \text{ (cm}^3\text{) (Daryadi et al. 1976)} \quad (2)$$

Where:
BJ : Wood density (g cm^{-3})
BK : Wood dry weight (g)
V : Wood volume (cm^3)

In order to measure wood density, we cut the part of around branches with branch length up to 20 cm and measured the diameter of pieces of branches, total wood fresh weight and wood fresh weight sample regions (10 cm), and for wood dry weight sample were cut into (10 cm) in length, and these were over dried with temperature 100^0C within 48 hours of constant weight. To calculate leaves biomass was used with the formula:

$$BO = Bks \text{ x } Bbt / Bbs \text{ (SNI 2011)} \quad (3)$$

Where:
BO : organic matter (leaves biomass) → (leaf biomass) (g)
Bbt : leaf fresh weight total (g)
Bks : leaf dry weight sample (g)
Bbs : leaf fresh weight sample (g)

To find stem biomass the allometry equation was used which was introduced by Chave et al. (2005). This equation is the basis of the allometry used by Chave et al. (2005) with dividing humid climate zone (1500-4000) mm $year^{-1}$, adjusted to the study sites having annual precipitation is 1800 mm:

$$BAP = 0.0509 \text{ x } \rho D^2 H \text{ (Chave et al. 2005)} \quad (4)$$

Where:
BAP : biomass tree stems (g/stem) → tree stems biomass (g/stem)
ρ : wood density (g/cm^3)
D : diameter tree stem (cm)
H : the tree height (cm)

To find the amount of carbon content, the tree stems biomass was multiplied by the value of 0.47 according to SNI (2011). In each species of trees the parameter of leaves consisting of the total amount leaves, the total fresh weight, total fresh weight of sample, total dry weight, dry weight of samples, and total amount of leaves area was calculated. The leaves area were measured in the laboratory of the Faculty of Animal Husbandry, Udayana University, Bali, Indonesia using a leaf electric meters.

The relation between amounts of leaves, leaves biomass, and value of carbon with the tree height has been analyzed for all species. The regression value to all species can be seen in Table 2.The comparison between tree height with crown thickness and comparison between the total amount of wood carbon and leaves carbon presented in the form of Figure 5.

RESULTS AND DISCUSSION

The species composition of mangrove species is shown in Table 1 which found in the study plot.

Table 1. Species composition and wood density (g/cm^3) of mangrove tree species in the plot (80<H≤410) cm

Species	Family	Wood density g/cm^3	Individuals (per 400 m^2)	Total of Samples trees
Rhizophora mucronata	Rhizophoraceae	0.79	4	3
Rhizophora apiculata	Rhizophoraceae	0.86	4	3
Rhizophora stylosa	Rhizophoraceae	0.91	4	3
Bruguiera gymnorrhiza	Rhizophoraceae	0.73	5	3
Ceriops tagal	Rhizophoraceae	0.88	6	3
Sonneratia alba	Sonneratiaceae	0.65	3	3
Avicennia alba	Avicenniacea	0.68	4	3
Lumnitzera racemosa	Combretaceae	0.74	3	3
Xylocarpus moluccensis	Malvaceae	0.51	3	3
Phempis acidula	Lyctroceae	0.00	3	3
Aegiceras corniculatum	Myrsinaceae	0.51	2	-
Excoecaria agallocha	Euphorbiaceae	0.726	1	-
Derris trifoliata	Leguminosae	-	1	-
Acrostichum aureum	Pteridaceae	-	1	-
Acanthus ilicifolius	Acanthaceae	-	1	-
Sesuvium portulacastrum	Aizoaceae	-	3	-

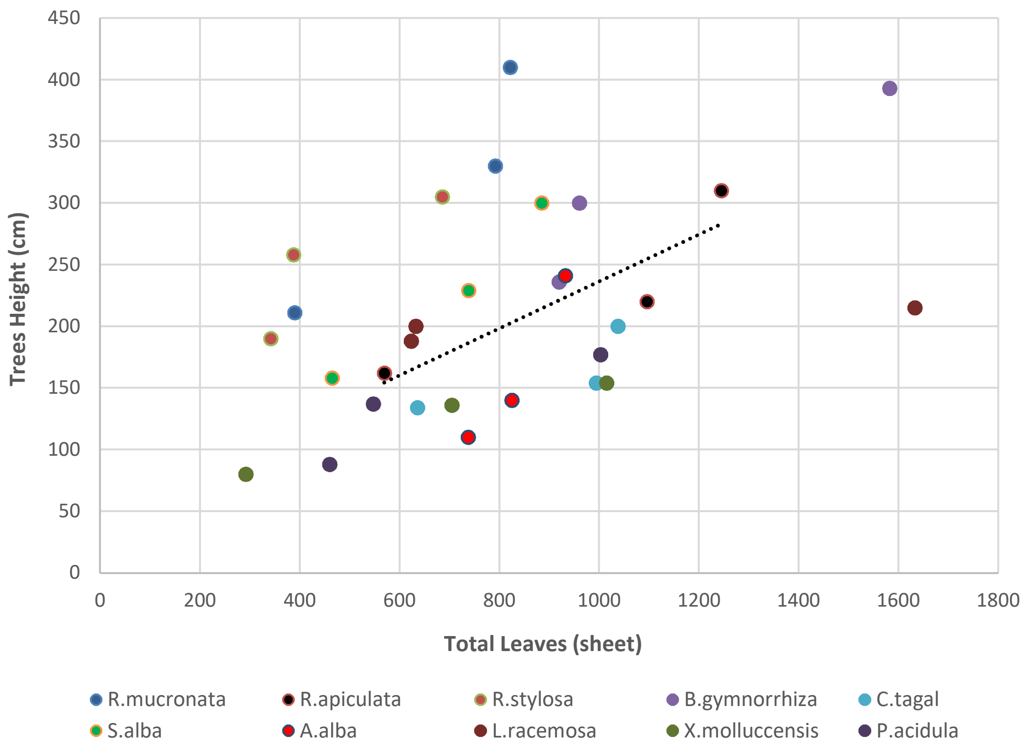


Figure 1. Regression of the leaves number (sheet) and trees height (cm)

The relationship between the number of leaves and the tree height

The relationship between the number of leaves and tree height for ten mangrove species can be seen in Figure 1.

In each species, total amount of leaves per tree increased with tree height from smallest tree up to highest tree. The total amount of leaves increase, then followed by increase in tree height. In every mangrove species sampled, leaf vertical distribution shows the leaf expansion phase with the regression equation of all mangrove species can be seen in (Table 2).

The height of the trees from of varies sample each individual showing the total number of leaves increased as the development phase of leaves so that the number of leaves for all species is still relatively growing as shown in Figure 1.

The result of these research indicated that most leaves were supported by the high light intensity (full of sunlight), because all mangrove species belong to the category of overstory species.

For each mangrove species the leaves characteristic of were defined with the data about the total area of leaves (cm^2), total fresh weight of leaves (g) and the total amount of leaves (sheet), specific leaf area (cm^2/g), leaf area(cm^2) and fresh leaf weight (g) in each species could be seen in Table 3 and 4.

The total amount of leaves which were varied in each species ranged from 471.90 sheets for *R. stylosa* and 1154.23 sheets to *B. gymnorrhiza* (Table 5).

Vertical distribution of leaves biomass and leaves carbon in each mangrove species

The vertical analysis of leaves distribution, biomass and leaf carbon content were carried out for ten mangrove species. The analysis showed that the vertical distribution of leaves varied for all tree species in Figure 2. Comparison of total leaves, leaves biomass, and leaves carbon among species can be seen in Figure 3.

The crown thickness is the height of top crown to bottom crown in each tree species, where some leaves occur. The analysis showed that in each species the leaves were classified into multilayer type. The comparison between tree height and the thickness of crown increased with the addition of another crown that may be caused by the number of leaves in leaf increasing phase. The crown thickness can be seen in Figure 4 with their standard deviations (Table 6).

The relationship between the photosynthesis organ and the non-photosynthesis organ

The vertical distribution of non-photosynthesis organs (stems) and photosynthesis organ (leaves) were presented in the forms of tree height, leaves biomass and absorption of carbon, and showed the same form although in each species have different sizes of trees.

The comparison between photosynthesis organs and non-photosynthesis organs either in the form of crown thickness as the total amount of leaves, leaves biomass and carbon of leaves and the form of tree height, as the wood biomass and wood carbon absorption, were presented in the form of Figure 5.

The ratio between photosynthesis organs (leaves carbon) and non-photosynthesis organs (wood carbon) could influence to productivity of biomass and carbon per unit in each species. The ratio of leaves carbon (F) against wood carbon as the non-photosynthesis organs (C) has been made in leaf-increasing phase. Each species is having the ratio of C/F varying as shown in Table 7.

Table 2. Regression value of leaf number (sheet) and tree height (cm)

Species	Equation	R^2
R. mucronata	$y = 0.3901x + 56.424$	$R^2 = 0.883$
R. apiculata	$y = 0.1905x + 45.825$	$R^2 = 0.8215$
R. stylosa	$y = 0.2709x + 123.18$	$R^2 = 0.7653$
B. gymnorrhiza	$y = 0.1988x + 80.18$	$R^2 = 0.8743$
C. tagal	$y = 0.1224x + 53.835$	$R^2 = 0.6353$
S. alba	$y = 0.3282x + 0.5284$	$R^2 = 0.9704$
A. alba	$y = 0.6828x-404.26$	$R^2 = 0.9412$
L. racemosa	$y = 0.021x + 180.79$	$R^2 = 0.8096$
X. moluccensis	$y = 0.1041x + 53.488$	$R^2 = 0.9581$
P. acidula	$y = 0.1389x + 40.917$	$R^2 = 0.8252$

Table 3. Total leaves/tree (sheet), average leaf fresh weight/tree (g), and average leaf area/tree (cm^2) in leaf-increasing phase

Species	Total sample trees	Ranges of height (cm)	Total Leaves/tree	Average leaf fresh weight/tree (g)	Average Leaf area/tree (cm^2)
R. mucronata	3	211-410	668.00	0.0178	5.07
R. apiculata	3	162-310	970.23	0.0085	3.33
R. stylosa	3	190-305	471.90	0.0143	2.73
B. gymnorrhiza	3	236-393	1154.23	0.0100	3.81
C. tagal	3	134-200	889.40	0.0846	2.20
S. alba	3	158-300	696.23	0.0242	2.51
A. alba	3	110-241	831.77	0.0253	1.33
L. racemosa	3	188-215	963.03	0.0223	0.89
X. moluccensis	3	80-154	670.67	0.0579	2.13
P. acidula	3	88-177	670.17	0.0610	1.24

Table 4. Specific to leaf area (cm^2/g)

Species	Leaf area (cm^2)	Leaf fresh weight (g/sheet)	Specific of leaf area (sheet) (cm^2/g)
R. mucronata	5.07	0.0178	284.831
R. apiculata	3.33	0.0085	391.765
R. stylosa	2.73	0.0143	190.909
B. gymnorrhiza	3.81	0.0100	381.000
C. tagal	2.20	0.0846	26.005
S. alba	2.51	0.0242	103.719
A. alba	1.33	0.0253	52.569
L. racemosa	0.89	0.0223	39.910
X. moluccensis	2.13	0.0579	36.788
P. acidula	1.24	0.0610	20.328

Table 5. Total leaves (sheet), for each mangrove tree

Species		Total leaves (sheet) I	II	III	X	$\overline{X}$	Total leaves/ trees
R. mucronata	Top crown	136	265	38	439.00	146.33	668.00
	Middle crown	291.9	226.1	171	689.00	229.67	
	Bottom crown	394	301	181	876.00	292.00	
R. apiculata	Top crown	298	139	92	529.00	176.33	970.23
	Middle crown	286	141.7	230	657.70	219.23	
	Bottom crown	512	289	923	1.724.00	574.67	
R. stylosa	Top crown	83	72	60	215.00	71.67	471.90
	Middle crown	147.8	184.9	124	456.70	152.23	
	Bottom crown	157	429	158	744.00	248.00	
B. gymnorrhiza	Top crown	443	112	243	798.00	266.00	1154.23
	Middle crown	375.3	100.5	275.6	751.40	250.47	
	Bottom crown	764	707.3	442	1.913.30	637.77	
C. tagal	Top crown	153	100	174	427.00	142.33	889.40
	Middle crown	370	313.3	160	843.30	281.10	
	Bottom crown	514.8	581	302.1	1.397.90	465.97	
S. alba	Top crown	100	108	96	304.00	101.33	696.23
	Middle crown	142.6	169	114.1	425.70	141.90	
	Bottom crown	496	608	255	1.359.00	453.00	
A. alba	Top crown	132	131	127	390.00	130.00	831.77
	Middle crown	253.2	158.4	112.7	524.30	174.77	
	Bottom crown	440	643	498	1.581.00	527.00	
L. racemosa	Top crown	221	102	112	435.00	145.00	963.03
	Middle crown	148.8	176.3	562	887.10	295.70	
	Bottom crown	263	345.2	958.8	1.567.00	522.33	
X. moluccensis	Top crown	132	39	84	255.00	85.00	670.67
	Middle crown	283	52	183	518.00	172.67	
	Bottom crown	600	201	438	1.239.00	413.00	
P. acidula	Top crown	106	38	39	183.00	61.00	670.17
	Middle crown	193	94	131	418.00	139.33	
	Bottom crown	248.5	871	290	1.409.50	469.83	

Note: X = Total leaves (sheet); $\overline{X}$ = Average of leaves (sheet).

Table 6. Standard deviation of tree height and crown thickness

Species	$\overline{X}$ Trees height (cm)	SD trees height	$\overline{X}$ Crown thickness (cm)	SD Crown thickness
R. mucronata	317.00	317.00 ± 211.33	258.67	258.67 ± 172.44
R. apiculata	230.67	230.67 ± 153.78	201.00	201.00 ± 134.00
R. stylosa	251.00	251.00 ± 167.33	212.67	212.67 ± 141.78
B. gymnorrhiza	309.67	309.67 ± 206.44	285.33	285.33 ± 190.22
C. tagal	162.67	162.67 ± 108.44	142.67	142.67 ± 95.11
S. alba	229.00	229.00 ± 152.67	183.00	183.00 ± 122.00
A. alba	163.67	163.67 ± 109.11	125.33	125.33 ± 83.56
L. racemosa	201.00	201.00 ± 134.00	196.00	196.00 ± 130.67
X. moluccensis	123.33	123.33 ± 82.22	104.67	104.67 ± 69.78
P. acidula	134.00	134.00 ± 89.33	126.00	126.00 ± 84.00

Note: SD = Standard deviation; $\overline{X}$ = Average

Table 7. Ratio of wood carbon (C) (g) and leaves carbon (F) (g)

Species	Trees height (cm)	Wood biomass (g)	Wood carbon (C)(g)	Crown thickness (cm)	Leaves biomass (g)	Leaves carbon (F) (g)	Ratio C/F
R. mucronata	317.00	180.92	84.92	258.67	62.08	29.18	2.91
R. apiculata	230.67	53.69	25.23	201.00	51.12	24.03	1.05
R. stylosa	251.00	61.40	38.86	212.67	47.87	22.5	1.73
B. gymnorrhiza	309.67	134.85	63.38	285.33	65.75	30.87	2.05
C. tagal	162.67	117.88	55.40	142.67	20.94	9.84	5.63
S. alba	229.00	135.04	63.47	183.00	24.01	11.29	5.62
A. alba	163.67.	15.01	7.06	125.33	22.07	10.37	0.68
L. racemosa	201.00	199.72	93.87	196.00	20.97	9.86	9.52
X. moluccensis	123.33	45.38	21.33	104.67	19.48	9.15	2.33
P. acidula	134.00	0.00	0.00	126.00	11.3	5.31	0.00

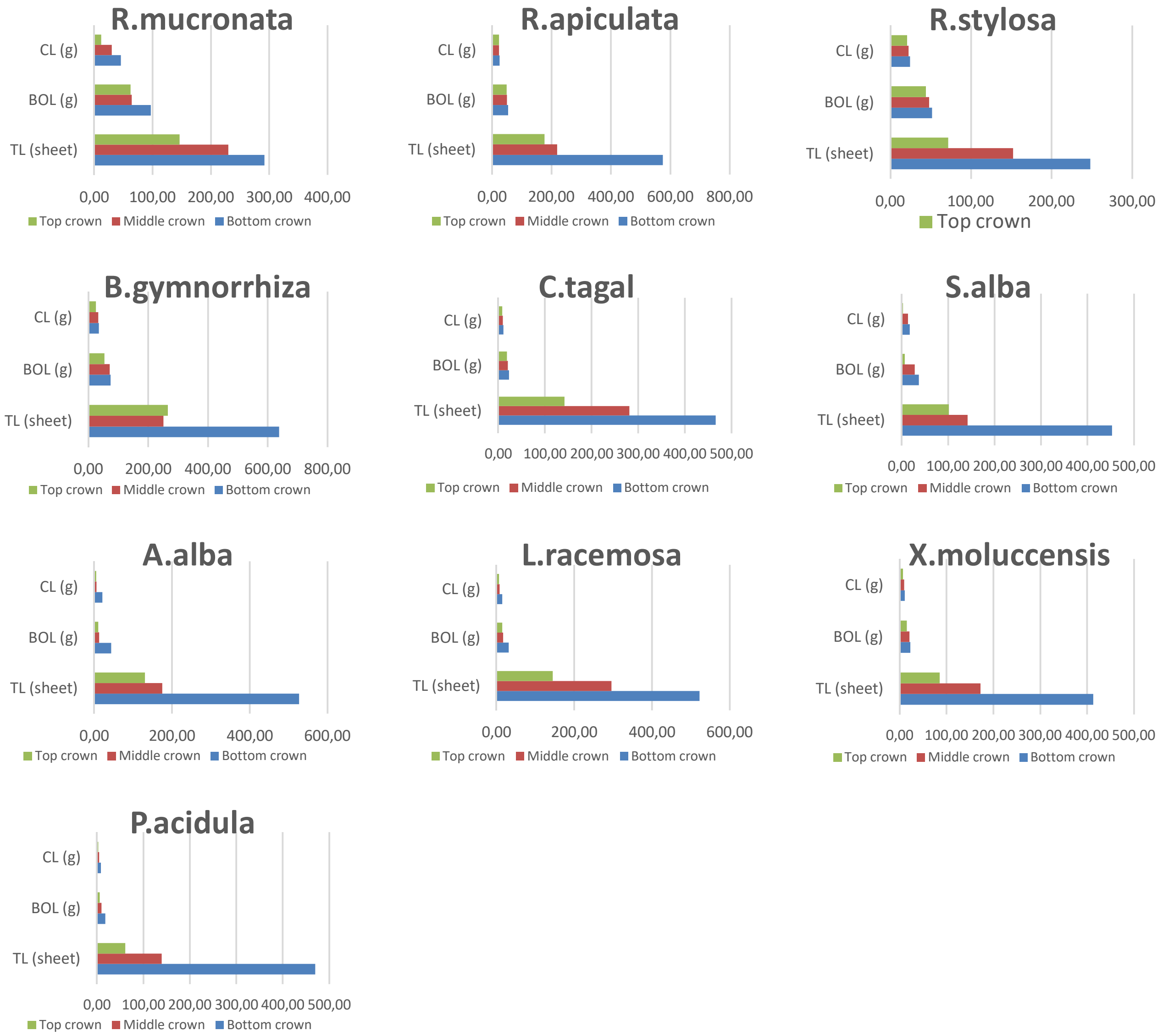
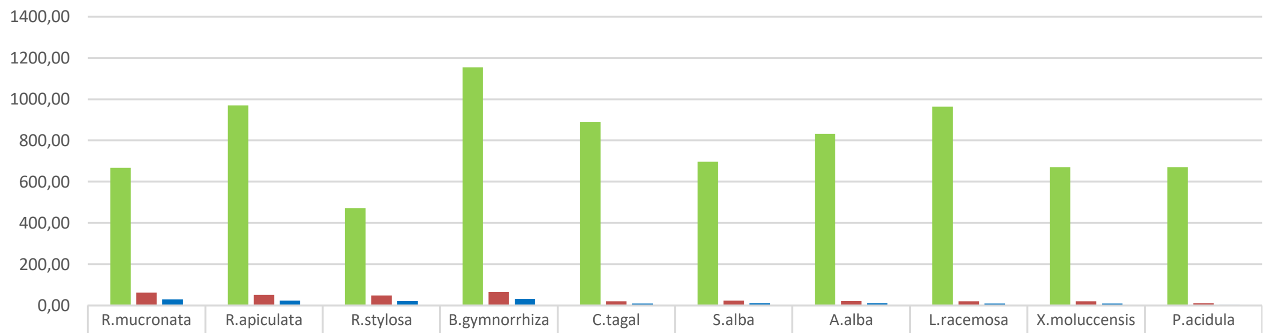


Figure 2. The distribution of total leaves (TL) (sheet), leaves biomass (BO_L) (g), and leaves carbon (C_L) (g)



	R.mucronata	R.apiculata	R.stylosa	B.gymnorrhiza	C.tagal	S.alba	A.alba	L.racemosa	X.moluccensis	P.acidula
TL (sheet)	668,00	970,23	471,90	1154,23	889,40	696,23	831,77	963,03	670,67	670,17
BOL (g)	62,08	51,12	47,87	65,75	20,94	24,01	22,07	20,97	19,48	11,3
CL (g)	29,18	24,03	22,5	30,87	9,84	11,29	10,37	9,86	9,15	5,31

Figure 3. Comparison of total leaves (TL) (sheet), leaves biomass (BO_L)(g), and leaves carbon (C_L)(g)

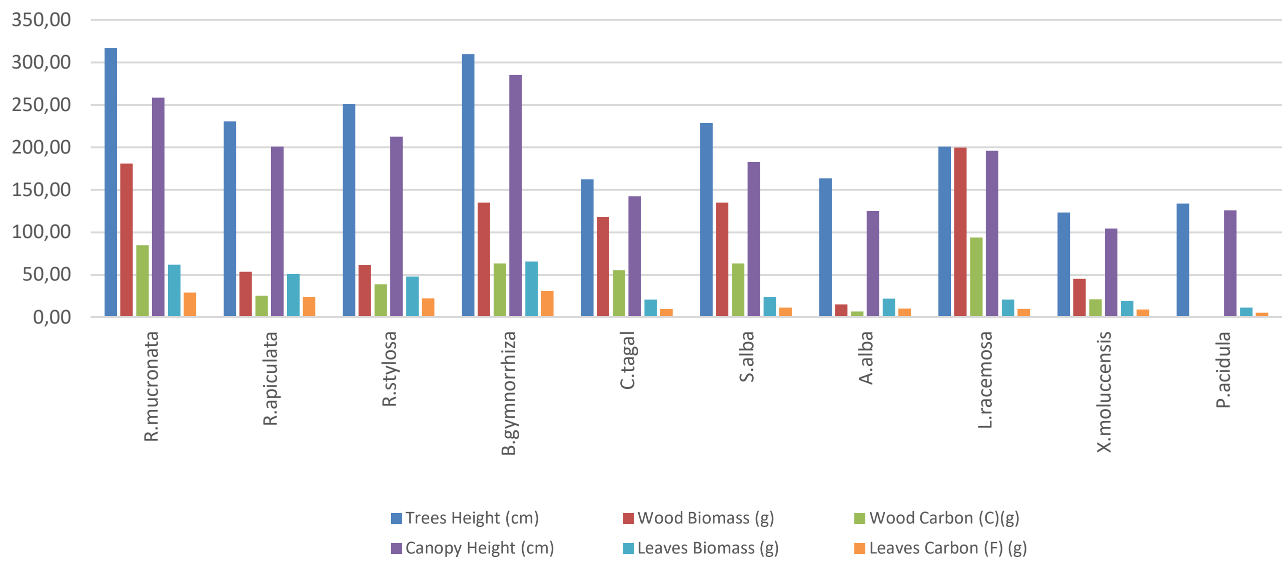


Figure 5. The comparison of trees height, wood biomass, wood carbon, and crown thickness, leaves biomass, leaves carbon

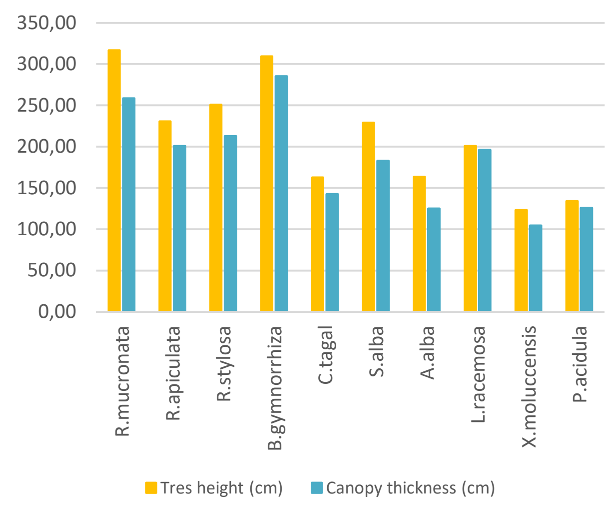


Figure 4. The comparison of tree height and crown thickness

Discussion

The relationship between the total amount of leaves and tree height in ten mangrove species showed that each species still at the leaf increasing phase. In the leaf increasing phase, tree height was followed by the total amount of leaves that formed crown layers at the top, middle and bottom part of each tree. In each species, the total amount of leaves did not constant, but continues to grow as seen in Figure 1 with regressions that evaluated positive value as shown in Table 2. This condition possibly was caused by the tree age of the species, because these trees were still young (approximately about 3 years of age), and also perhaps due to the land conditions that were poor, dominated by the texture of sandy soil. Moreover, upper layer of soil did not yet form a layer with low total density of trees at 16 species in a plot size of 20 m x 20 m.

Moller (1947) argued that leaves biomass would increase gradually with age. Kittredge (1944) also proposed that the leaves biomass increase with age and begins to be constant at 60-90 years of age. Hatinya et al. (1966) stated that leaves biomass increase with increasing of site index. In general, high leaves biomass is found in a good site condition.

The total amount of leaves varied from species. The larger or smaller the leaf weight in each species depends on the specific size of the leaf area, the larger the specific leaf area depends on the leaf area and the leaf weight of each tree species as shown in Table 3 and 4. Table 4 indicated that the *Rhizophora apiculata* showed the highest specific leaf area among others, namely 391.765 cm^2/g because it had the highest leaf area (3.33 cm^2) high with leaf weight only 0.0085 g. Likewise, *P. acidula* had leaf area of 1.24 cm^2 with the leaf weight of 0.0610 g showing a smallest specific leaf area of about 20.328 cm^2/g.

Horn (1971) divides into two types of adaptive crown that affect the development of the crown, the first development is a multilayer leaf distribution type and the second is a monolayer type which is a leaf development character formed from the overlap of young leaves on an open and closed canopy layer. In the leaf-increasing phase type, the evergreen species have a multi-layer leaf distribution (Horn 1971). It is predicted that the number of leaves will be greater than the type of mono-layer species. In addition, the distribution of vertical leaves can be calculated by the difference in leaf number on each layer of the tree crown.

The shape of the tree crown is attributed of the development of the shoots at the tip of tree as well as that the branch buds, which can be seen in the vertical distribution of the leaves and organs supporting the stem and tree branches. Waller and Steingraeber (1986), found that the adaptive architecture of tree form collective response of modular unit in the plants. The leaves are concentrated in the horizontal layer where each leaf effectively spreads and occupies the gap, to obtain sunlight. It appears that all mangrove species used as samples are concentrated in the multi-layer of the crown. The thickness of the crown is higher than the mono-layer type species.

The ratio between the amount of leaf carbon (F) and wood carbon (C) increases with tree height. Givnish (1982) found that the proportion of organs support the number of leaves such as stems, branches, and twigs is increasing very rapidly as the growth of tree height increases. The resulting net production is not only from the average of photosynthesis and respiration per unit of biomass, but also are influenced by the number of leaves to support non-photosynthesis organ of stem biomass, branches and twigs of trees. Dry weight of leaves as photosynthesis organ varies within the ratio of leaf weight and leaf area. As a result, the dry weight of the material produced during the growing season is dependent on the amount of dry weight difference occurring at the beginning of the growing season, namely on average photosynthesis and respiration results, distribution of new photosynthesis organ on different types of leaf distribution, specific leaf area and mean difference of dead organ which cause loss weight.

In conclusion, the research on the adaptation of tree architecture in mangrove forests is still very limited, but has been widely used both in tropical forests and in subtropical forest areas. The results showed that the relationship between tree height and number in leaves of ten mangrove species was positive with the value of (r) regression varying from the smallest value ($R^2 = 0.6353$) owned by *C. tagal* and the highest value ($R^2 = 0.9704$) by *Sonneratia alba*. It can be concluded that the total number of leaves per tree is still relatively increased with the increase of tree height from the smallest tree to the highest tree and still in the leaf increasing phase. The total number of leaves varies within each species between 471.90 sheets for *Rhizophora stylosa* and 1154.23 sheets for the *B. gymnorrhiza* species. Comparison of the number of leaves, leaves biomass, and leaves carbon shows the same distribution, starting at the top of the crown, to the middle and bottom, shows the development of crown units represented the increasing phase of either for each species, and can be classified into multilayer leaf distribution types.

The amount of leaf biomass and leaf carbon content in each species depends on leaf area (cm^2), leaf weight (g/sheet) and specific leaf area. *R. apiculata* leaf showing the largest value of specific leaf area, is 391.765 cm^2/g and the smallest at *P. acidula* with the value of 20.238 cm^2/g. The ratio between photosynthetic organ and non-photosynthetic organ is influenced by the biomass productivity of carbon leaves per leaf unit in each species. This ratio creates a continuous leaf increasing phase, and each species has a variable C/F ratio, the largest lies in *Lumnitzera racemosa* with C/F is 9.52, and the lowest in *Avicennia alba* with C/F is 0.68. This means that the greater the value of C/F, leaf unit or leaf carbon can form larger stems of trees and vice versa.

ACKNOWLEDGEMENTS

We thank the International Seminar committee of the Society for Indonesian Biodiversity, which has given us the opportunity to attend in this seminar and also thank the Head of Climate Change Mitigation and Forest Fire and Land Region of Java, Bali, and Nusa Tenggara that has assisted us in providing useful information.

REFERENCES

Ardhana IPG, Takeda H, Sakimoto M, Tsutsumi T. 1988. The vertical foliage distributions of six understory tree species in a Chamaecyparis obtusa Endl. Forest. Structure and Function Trees. Springer Verlag, Berlin.

Camacho LD, Gevana DT, Carandang AP, Camacho SC, Combalicer EA, Rebugio LL, Youn TC. 2011. Tree biomas and carbon stock of a community-managed mangrove forest in Bohol, Philippines. For Sci Technol 7 (4): 161-167.

Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Folster H, Fromard F, Higuchi N, Kira T, Lescure J-P, Nelson BW, Ogawa H, Puig H, Riera B, Yamakura T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145 (1): 87-99.

Chazdon RL. 1985. Leaf display, canopy structure and light interception of two understory palm species. Am J Bot 72: 1493-1502

Chazdon RL. 1986. The cost of leaf support in understory palms. Economy versus safety. Am Nat 127: 9-30

Daryadi L, Meulenhoff LMW, Soediono SY, Soemawidjaja U, al-Rasyid H, Silitonga T, Wiroatmodjo P, Martadiwangsa ES, Soekandi, Madyana T, Mardyono, Baddrudin TA, Soeparmo, Kadir K, Djokosoetarmo, Sidabutar M. 1976. Vademecum Kehutanan Indonesia. Direktorat Jenderal Kehutanan, Departemen Pertanian, Jakarta. [Indonesian]

Fatoyinbo TE, Simard M. 2013. Height and biomass of mangroves in Africa from ICESat/GLAS and SRTM. Intl J Rem Sens 34 (2): 668-681.

Givnish TJ. 1982. On the adaptive significance of leaf height in forest herbs. Am Nat 20: 353-381

Hatinya K, Tochiaki K, Narita T. 1966. Analysis of growth in natural forests of *Pinus densiflora*: relationships between site quality and growth. Trans 76th Mtg Jap For Soc (1965): 161-162.

Horn HS. 1971. The adaptive geometry of trees. Princeton University Press, Princeton, USA.

ITTO. 2013. Penyusunan baseline data pengelolaan ekosistem mangrove di Pulau Bintan. ITTO Project RED-PD 064/11 Rev. 2 (F). Direktorat Jenderal Bina Pengelolaan Daerah Aliran Sungai dan Perhutanan Sosial Kementerian Kehutanan, Jakarta. [Indonesian]

Kittredge, 1944. Estimation of the amount of foliage of trees and stands. Journal forestry. 42:905-912

Moller CM. 1947. The effect of thinning, age, and site on foliage, increment, and loss of dry matter. Journal of forestry. 45:393-404

Nicola A, Pickett STA. 1983. The adaptive architecture of shrub canopies: leaf display and biomass allocation in relation to light environment. New Phytol 93: 301-310

Njana MA, Zahabu E, Malimbwi RE. 2017. Carbon stocks and productivity of mangrove forests in Tanzania. Southern Forests. DOI: 10.2989/20702620.2017.1334314

Sahu SC, Kumar M, Ravindranath NH. 2016. Carbon stock in natural and planted mangrove forests of Mahanadi mangrove Wetland, East Coast of India. Curr Sci 110 (12): 2334-2341.

Schulze ED, Kuppers M, Matyssek R. 1986. The role of carbon balance and branching pattern in the growth of woody species. In: Givinish TJ (ed) On the Economy of Plant Form and Function. Cambridge University Press, New York.

Sitoe AA, Mandlate LJC, Guedes BS. 2014. Biomass and carbon stocks of Sofala Bay Mangrove Forest. Forests 5 (8): 1967-1981.

SNI. 2011. SNI No. 7724: 2011 Pengukuran dan penghitungan cadangan karbon pengukuran lapangan Untuk penaksiran cadangan karbon hutan (Ground-based forest carbon accounting). Badan Standarisasi Nasional, Jakarta. [Indonesian]

Taberima S, Nugroho YD, Murdiyarso D. 2014. The distribution of carbon stock in selected. mangrove ecosystem of Wetlands Papua: Bintuni, Teminabuan, and Timika, Eastern Indonesia. Internasional Conference on Chemical, Environment & Biological Sciences. Kuala Lumpur, Malaysia.

Waller DM, Steingraeber DA. 1986. Branching and modular growth. In: Jackson JBC, Buss LW, Cook PE (eds.) Population Biology and Evolution of Clonal Organisms. Yale University Press, New Haven, USA.

Zanne AE, Lopez-Gonzalez G, Coomes DA, Ilic J, Jansen S, Lewis SL, Miller RB, Swenson NG, Wiemann MC, Chave J. 2009. Data from: towards a worldwide wood economics spectrum. Dryad Digital Repository 2009. DOI: 10.5061/dryad.234.

The distribution of vertical leaves and leaves biomass on ten mangrove species at Ngurah Rai Forest Park, Denpasar, Bali, Indonesia

by I Putu Gede Ardhana

BIODIVERSITAS
Volume 19, Number 3, May 2018
Pages: 918-926

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d190322

The distribution of vertical leaves and leaves biomass on ten mangrove species at Ngurah Rai Forest Park, Denpasar, Bali, Indonesia

I PUTU GEDE ARDHANA[1,♥], I M.G.S. RIMBAWAN[2], PUJO NUR CAHYO[2], YUYUN FITRIANI[3], SISKA ROHANI[4]

[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Udayana. Jl. Raya Kampus Unud, Jimbaran, Kuta Selatan, Badung 80361, Bali, Indonesia. Tel./fax +62-361-701954, ♥email: crescentbali@ind[illegible].id

[2]Climate Change Control and Forest Fire and Land Border of The Region of Java, Bali, and Nusa Tenggara. Jl. Bypass Ngurah Rai Km. 21, Suwung Kauh, Pemogan, Denpasar 80221, Bali, Indonesia

[3]Faculty of Agriculture, Universitas Udayana. Jl. Raya Kampus Unud, Jimbaran, Kuta Selatan, Badung 80361, Bali, Indonesia

[4]Program of Environmental Science, School of Graduates, Universitas Udayana. Jl. P.B. Sudirman, Denpasar 80232, Bali, Indonesia

Manuscript received: 12 December 2017. Revision accepted: 27 April 2018.

Abstract. *Ardhana IPG, Rimbawan IMGS., Cahyo PN, Fitriani Y, Rohani S. 2018. The distribution of vertical leaves and leaves biomass on ten mangrove species at Ngurah Rai Forest Park, Denpasar, Bali, Indonesia. Biodiversitas 19: 918-926.* The distribution of vertical leaves and leaves biomass which forms the mangrove crown divides into three parts, namely the top part, the middle part, and the bottom part. Total amount leaves on any parts are highly variable depending on height of each species. The relationship between the height of tree with the crown thickness depended on total leaves of each crown on each species as well as the relationship between the total leaves biomass of each crown on each species, with the height and volume of tree stems, also has variation on each mangrove species. Author examined the relationship between the photosynthetic organs with non-photosynthetic organs, especially on stems in each species. The high total amount of leaves and large total amount leaves biomass deeply is depended on diameter and growth height which are presented in the form of stem volumes. On the relationship between the photosynthetic organs and non-photosynthetic organs on each mangrove species, also has been examined. The higher total amount of leaves or the total amount of leaves biomass largely depended on the stem volume of mangroves. This indicates that the production of photosynthetic organ either in the form of the total amount of leaves or the total amount of leaves biomass serve to support growth of the stem mangrove trees (height of stem, diameter of stem and volume of stem).

Keywords: Adaptation, multi-layer, mangrove species, vertical leaves and leaves biomass distributions

INTRODUCTION

This study includes a form of adaptation of tree architecture both in the tropics and in the temperate regions. This architectural form is heavily influenced by the sunlight received by the tree crown from the top of the tree to the lowest canopy of the tree. Form of tree architecture adaptation is in the form of monolayer and multilayer. Of the 10 mangrove species exhibit a multilayer adaptive form with different distribution of leaves from the top of the crown, middle and bottom. Meanwhile, if the monolayer form of the number of leaf distribution shows the number of leaves from top to bottom of the crown is uniform because it gets a little sunlight under the shade of tree stands in this study is not found form of monolayer architecture adaptation. The adaptative architecture of trees in tropical forests has been examined in successive (Chazdon 1986; Givnish 1982). The research on adaptative architecture of trees on mangrove forest in tropical does not exist yet, but has done a lot of research on the distribution of carbon stocks, and productivity of mangrove forest (see Camacho et al. 2011; Fatoyinbo and Simard 2013; Sitoe et al. 2014; Taberima et al. 2014; Sahu et al. 2016; Njana et al. 2017). The research on adaptive architecture of tree in the temperate regions has also been done (see Horn 1971; Nicola and Pickets 1983; Ehlesinger and Kenneths 1986; Ardhana et al. 1988). These researchers related with adaptive architecture of trees such as the distribution of leaves pattern, the leaves biomass and the absorption of carbon. The distribution of leaves pattern, leaves biomass, absorption of carbon with growth of the stem are major causes of the highlight of environmental constraints, such as potential total amount leaves at the bottom, middle and top layer of crown to absorb sunlight (Chazdon 1985, 1986). The adaptive architecture of trees has possibility which forms the response of adaptive group of leaves in unit trees (Waller and Steingraeber 1986); adaptive photosynthesis (Givnish 1982); the role of carbon balance and the branching pattern in growth of trees (Schulze et al. 1986). Those become major causes of stress for environmental constraint that occurs in the part of crown trees. If overstorey does not have full of sunlight, the growth of crown trees is varied layers such as bottom, middle and top layers.

The effective distribution of leaves or leaves biomass is very important for the survival of living leaves in all species of trees. The distribution and growth of crown structure in overstory and understory trees are commonly subject to various constraints such as limited light condition in the crown trees (Chazdon 1985, 1986; Taberima et al. 2014). The adaptive architecture of trees may form collective response of modular unit in the plants

(Waller and Steingraeber 1986; Taberima et al. 2014) for the common environmental condition of leaves in the layer of crown of overstory species. The research about the distribution of leaves and the leaves biomass are associated with absorption of carbon in the atmosphere at both the photosynthesis (leaves) organs and non-photosynthesis (stem) organs, but for mangrove species, research is rare.

The purpose of this research is to compare the distribution pattern of vertical leaves and leaves biomass on ten mangrove species, and to understand the relationship between the photosynthesis organ and non-photosynthesis organs on each mangrove species.

MATERIALS AND METHODS

This study was carried out in the secondary forest of mangrove as former fishpond farms at Ngurah Rai Forest Park, Denpasar, Bali, Indonesia (115^{0}9'-115^{0}14'E, 8^{0}42'-8^{0}49'S) 3.5 km east of Denpasar City. The sphere of temperature ranges from 22^{0}C-28^{0}C and annual precipitation are 1,800 mm, with climate type of E (Schmidt Fergusson). A study plot which has size of 20 m x 20 m was used in this Forest Park. The soil conditions are poor as former fishpond farms and the soil profile does not show the developed mineral soil layers (a layer).

The crown of any tree species was divided into three parts of crown layers which are part of top layer, middle and bottom layer. In the plot, the light condition from the sun is state of being open. All species belong to the overstory species, were identified and noted, in order to measure species density. But the leaves distribution on the top layer, middle and bottom layer were different, and most distribution of leaves is part of multi-layer species. But in the bottom crown part, highest total amount leaves were showed, and also the amount of biomass content and carbon became high. Comparison between tree height and crown thickness with the total amount of carbon which absorbed by leaves as photosynthesis organs showed that there was closely relation to any carbon content of non-photosynthesis organs, especially the tree height of stems. In any species, the relation between amounts of leaves with tree height also varied with the value of *r* could be seen in Figure 1, so those were showing the positive relation.

The distribution of leaves, leaves biomass, and any carbon content of leaves were studied for ten dominant overstory species among others *Rhizophora mucronata, R. apiculata, R. stylosa, Bruguiera gymnorrhiza, Ceriops tagal, Sonneratia alba, Avicennia alba, Lumnitzera racemosa, Xylocarpus moluccensis* and *Phempis acidula*. The sum of the sample trees can be seen in Table 1, the sample of every tree species is divided vertically into three parts of layers, namely the top, the middle and the bottom part of layers, and total amount leaves in each part were calculated over the period of June to August 2016.

Biomass of photosynthesis organs and non-photosynthesis organs of ten mangrove species has been calculated. Non-photosynthesis organs were obtained from diameter, tree height and the form value in each stem of sample species were multiplied by the value of 0.7, then calculated the volume of stems with the formula:

$$V = \pi r^2 \times T \times 0.7 \text{ (Asy'ari et al. 2012)} \quad (1)$$

Where:
V : Volume
T : Tree height (cm)

While to obtain the wood density of stem, it was used the wood density from the table of Global Wood Density Data Base (Zanne et al. 2009; ITTO 2013), which has The International-Standard. But especially for *P. acidula* species, the formula cannot be found from the global wood density table. Hence to calculate the wood density we used this formula:

$$BJ = BK \text{ (g)}/V \text{ (cm}^3\text{) (Daryadi et al. 1976)} \quad (2)$$

Where:
BJ : Wood density (g cm^{-3})
BK : Wood dry weight (g)
V : Wood volume (cm^3)

In order to measure wood density, we cut the part of around branches with branch length up to 20 cm and measured the diameter of pieces of branches, total wood fresh weight and wood fresh weight sample regions (10 cm), and for wood dry weight sample were cut into (10 cm) in length, and these were over dried with temperature 100^{0}C within 48 hours of constant weight. To calculate leaves biomass was used with the formula:

$$BO = Bks \times Bbt / Bbs \text{ (SNI 2011)} \quad (3)$$

Where:
BO : organic matter (leaves biomass) → (leaf biomass) (g)
Bbt : leaf fresh weight total (g)
Bks : leaf dry weight sample (g)
Bbs : leaf fresh weight sample (g)

To find stem biomass the allometry equation was used which was introduced by Chave et al. (2005). This equation is the basis of the allometry used by Chave et al. (2005) with dividing humid climate zone (1500-4000) mm year^{-1}, adjusted to the study sites having annual precipitation is 1800 mm:

$$BAP = 0.0509 \times \rho D^2 H \text{ (Chave et al. 2005)} \quad (4)$$

Where:
BAP : biomass tree stems (g/stem) → tree stems biomass (g/stem)
ρ : wood density (g/cm^3)
D : diameter tree stem (cm)
H : the tree height (cm)

To find the amount of carbon content, the tree stems biomass was multiplied by the value of 0.47 according to SNI (2011). In each species of trees the parameter of leaves consisting of the total amount leaves, the total fresh weight, total fresh weight of sample, total dry weight, dry weight of samples, and total amount of leaves area was calculated. The leaves area were measured in the laboratory of the Faculty of Animal Husbandry, Udayana University, Bali, Indonesia using a leaf electric meters.

The relation between amounts of leaves, leaves biomass, and value of carbon with the tree height has been analyzed for all species. The regression value to all species can be seen in Table 2.The comparison between tree height with crown thickness and comparison between the total amount of wood carbon and leaves carbon presented in the form of Figure 5.

RESULTS AND DISCUSSION

The species composition of mangrove species is shown in Table 1 which found in the study plot.

Table 1. Species composition and wood density (g/cm^3) of mangrove tree species in the plot (80<H≤410) cm

Species	Family	Wood density g/cm^3	Individuals (per 400 m^2)	Total of Samples trees
Rhizophora mucronata	Rhizophoraceae	0.79	4	3
Rhizophora apiculata	Rhizophoraceae	0.86	4	3
Rhizophora stylosa	Rhizophoraceae	0.91	4	3
Bruguiera gymnorrhiza	Rhizophoraceae	0.73	5	3
Ceriops tagal	Rhizophoraceae	0.88	6	3
Sonneratia alba	Sonneratiaceae	0.65	3	3
Avicennia alba	Avicenniacea	0.68	4	3
Lumnitzera racemosa	Combretaceae	0.74	3	3
Xylocarpus moluccensis	Malvaceae	0.51	3	3
Phempis acidula	Lyctroceae	0.00	3	3
Aegiceras corniculatum	Myrsinaceae	0.51	2	-
Excoecaria agallocha	Euphorbiaceae	0.726	1	-
Derris trifoliata	Leguminosae	-	1	-
Acrostichum aureum	Pteridaceae	-	1	-
Acanthus ilicifolius	Acanthaceae	-	1	-
Sesuvium portulacastrum	Aizoaceae	-	3	-

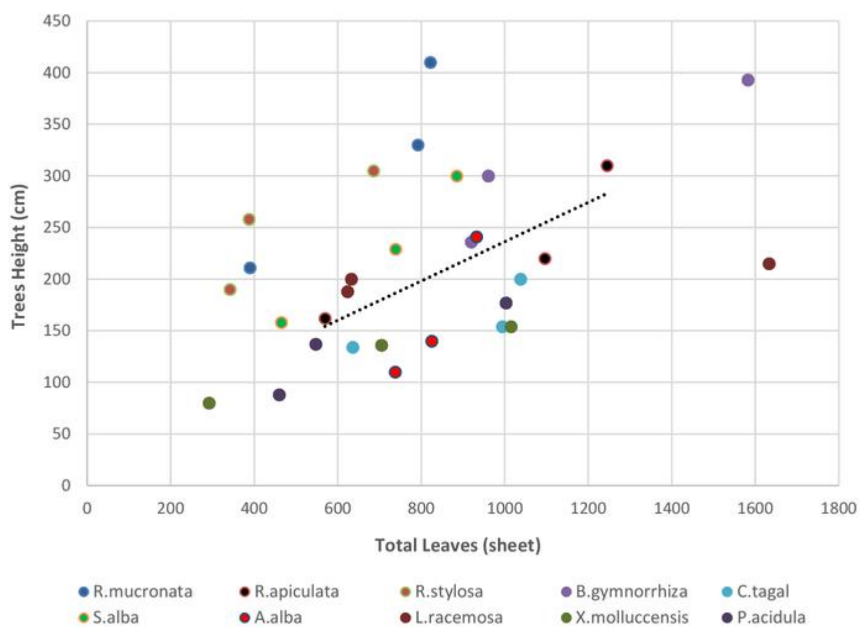


Figure 1. Regression of the leaves number (sheet) and trees height (cm)

The relationship between the number of leaves and the tree height

The relationship between the number of leaves and tree height for ten mangrove species can be seen in Figure 1.

In each species, total amount of leaves per tree increased with tree height from smallest tree up to highest tree. The total amount of leaves increase, then followed by increase in tree height. In every mangrove species sampled, leaf vertical distribution shows the leaf expansion phase with the regression equation of all mangrove species can be seen in (Table 2).

The height of the trees from of varies sample each individual showing the total number of leaves increased as the development phase of leaves so that the number of leaves for all species is still relatively growing as shown in Figure 1.

The result of these research indicated that most leaves were supported by the high light intensity (full of sunlight), because all mangrove species belong to the category of overstory species.

For each mangrove species the leaves characteristic of were defined with the data about the total area of leaves (cm^2), total fresh weight of leaves (g) and the total amount of leaves (sheet), specific leaf area (cm^2/g), leaf area(cm^2) and fresh leaf weight (g) in each species could be seen in Table 3 and 4.

The total amount of leaves which were varied in each species ranged from 471.90 sheets for *R. stylosa* and 1154.23 sheets to *B. gymnorrhiza* (Table 5).

Vertical distribution of leaves biomass and leaves carbon in each mangrove species

The vertical analysis of leaves distribution, biomass and leaf carbon content were carried out for ten mangrove species. The analysis showed that the vertical distribution of leaves varied for all tree species in Figure 2. Comparison of total leaves, leaves biomass, and leaves carbon among species can be seen in Figure 3.

The crown thickness is the height of top crown to bottom crown in each tree species, where some leaves occur. The analysis showed that in each species the leaves were classified into multilayer type. The comparison between tree height and the thickness of crown increased with the addition of another crown that may be caused by the number of leaves in leaf increasing phase. The crown thickness can be seen in Figure 4 with their standard deviations (Table 6).

The relationship between the photosynthesis organ and the non-photosynthesis organ

The vertical distribution of non-photosynthesis organs (stems) and photosynthesis organ (leaves) were presented in the forms of tree height, leaves biomass and absorption of carbon, and showed the same form although in each species have different sizes of trees.

The comparison between photosynthesis organs and non-photosynthesis organs either in the form of crown thickness as the total amount of leaves, leaves biomass and carbon of leaves and the form of tree height, as the wood biomass and wood carbon absorption, were presented in the form of Figure 5.

The ratio between photosynthesis organs (leaves carbon) and non-photosynthesis organs (wood carbon) could influence to productivity of biomass and carbon per unit in each species. The ratio of leaves carbon (F) against wood carbon as the non-photosynthesis organs (C) has been made in leaf-increasing phase. Each species is having the ratio of C/F varying as shown in Table 7.

Table 2. Regression value of leaf number (sheet) and tree height (cm)

Species	Equation	R^2
R. mucronata	$y = 0.3901x + 56.424$	$R^2 = 0.883$
R. apiculata	$y = 0.1905x + 45.825$	$R^2 = 0.8215$
R. stylosa	$y = 0.2709x + 123.18$	$R^2 = 0.7653$
B. gymnorrhiza	$y = 0.1988x + 80.18$	$R^2 = 0.8743$
C. tagal	$y = 0.1224x + 53.835$	$R^2 = 0.6353$
S. alba	$y = 0.3282x + 0.5284$	$R^2 = 0.9704$
A. alba	$y = 0.6828x-404.26$	$R^2 = 0.9412$
L. racemosa	$y = 0.021x + 180.79$	$R^2 = 0.8096$
X. moluccensis	$y = 0.1041x + 53.488$	$R^2 = 0.9581$
P. acidula	$y = 0.1389x + 40.917$	$R^2 = 0.8252$

Table 3. Total leaves/tree (sheet), average leaf fresh weight/tree (g), and average leaf area/tree (cm^2) in leaf-increasing phase

Species	Total sample trees	Ranges of height (cm)	Total Leaves/tree	Average leaf fresh weight/tree (g)	Average Leaf area/tree (cm^2)
R. mucronata	3	211-410	668.00	0.0178	5.07
R. apiculata	3	162-310	970.23	0.0085	3.33
R. stylosa	3	190-305	471.90	0.0143	2.73
B. gymnorrhiza	3	236-393	1154.23	0.0100	3.81
C. tagal	3	134-200	889.40	0.0846	2.20
S. alba	3	158-300	696.23	0.0242	2.51
A. alba	3	110-241	831.77	0.0253	1.33
L. racemosa	3	188-215	963.03	0.0223	0.89
X. moluccensis	3	80-154	670.67	0.0579	2.13
P. acidula	3	88-177	670.17	0.0610	1.24

Table 4. Specific to leaf area (cm^2/g)

Species	Leaf area (cm^2)	Leaf fresh weight (g/sheet)	Specific of leaf area (sheet) (cm^2/g)
R. mucronata	5.07	0.0178	284.831
R. apiculata	3.33	0.0085	391.765
R. stylosa	2.73	0.0143	190.909
B. gymnorrhiza	3.81	0.0100	381.000
C. tagal	2.20	0.0846	26.005
S. alba	2.51	0.0242	103.719
A. alba	1.33	0.0253	52.569
L. racemosa	0.89	0.0223	39.910
X. moluccensis	2.13	0.0579	36.788
P. acidula	1.24	0.0610	20.328

Table 5. Total leaves (sheet), for each mangrove tree

Species		Total leaves (sheet)			X	$\overline{X}$	Total leaves/ trees
		I	II	III			
R. mucronata	Top crown	136	265	38	439.00	146.33	668.00
	Middle crown	291.9	226.1	171	689.00	229.67	
	Bottom crown	394	301	181	876.00	292.00	
R. apiculata	Top crown	298	139	92	529.00	176.33	970.23
	Middle crown	286	141.7	230	657.70	219.23	
	Bottom crown	512	289	923	1.724.00	574.67	
R. stylosa	Top crown	83	72	60	215.00	71.67	471.90
	Middle crown	147.8	184.9	124	456.70	152.23	
	Bottom crown	157	429	158	744.00	248.00	
B. gymnorrhiza	Top crown	443	112	243	798.00	266.00	1154.23
	Middle crown	375.3	100.5	275.6	751.40	250.47	
	Bottom crown	764	707.3	442	1.913.30	637.77	
C. tagal	Top crown	153	100	174	427.00	142.33	889.40
	Middle crown	370	313.3	160	843.30	281.10	
	Bottom crown	514.8	581	302.1	1.397.90	465.97	
S. alba	Top crown	100	108	96	304.00	101.33	696.23
	Middle crown	142.6	169	114.1	425.70	141.90	
	Bottom crown	496	608	255	1.359.00	453.00	
A. alba	Top crown	132	131	127	390.00	130.00	831.77
	Middle crown	253.2	158.4	112.7	524.30	174.77	
	Bottom crown	440	643	498	1.581.00	527.00	
L. racemosa	Top crown	221	102	112	435.00	145.00	963.03
	Middle crown	148.8	176.3	562	887.10	295.70	
	Bottom crown	263	345.2	958.8	1.567.00	522.33	
X. moluccensis	Top crown	132	39	84	255.00	85.00	670.67
	Middle crown	283	52	183	518.00	172.67	
	Bottom crown	600	201	438	1.239.00	413.00	
P. acidula	Top crown	106	38	39	183.00	61.00	670.17
	Middle crown	193	94	131	418.00	139.33	
	Bottom crown	248.5	871	290	1.409.50	469.83	

Note: X = Total leaves (sheet); $\overline{X}$ = Average of leaves (sheet).

Table 6. Standard deviation of tree height and crown thickness

Species	$\overline{X}$ Trees height (cm)	SD trees height	$\overline{X}$ Crown thickness (cm)	SD Crown thickness
R. mucronata	317.00	317.00 ± 211.33	258.67	258.67 ± 172.44
R. apiculata	230.67	230.67 ± 153.78	201.00	201.00 ± 134.00
R. stylosa	251.00	251.00 ± 167.33	212.67	212.67 ± 141.78
B. gymnorrhiza	309.67	309.67 ± 206.44	285.33	285.33 ± 190.22
C. tagal	162.67	162.67 ± 108.44	142.67	142.67 ± 95.11
S. alba	229.00	229.00 ± 152.67	183.00	183.00 ± 122.00
A. alba	163.67	163.67 ± 109.11	125.33	125.33 ± 83.56
L. racemosa	201.00	201.00 ± 134.00	196.00	196.00 ± 130.67
X. moluccensis	123.33	123.33 ± 82.22	104.67	104.67 ± 69.78
P. acidula	134.00	134.00 ± 89.33	126.00	126.00 ± 84.00

Note: SD = Standard deviation; $\overline{X}$ = Average

Table 7. Ratio of wood carbon (C) (g) and leaves carbon (F) (g)

Species	Trees height (cm)	Wood biomass (g)	Wood carbon (C)(g)	Crown thickness (cm)	Leaves biomass (g)	Leaves carbon (F) (g)	Ratio C/F
R. mucronata	317.00	180.92	84.92	258.67	62.08	29.18	2.91
R. apiculata	230.67	53.69	25.23	201.00	51.12	24.03	1.05
R. stylosa	251.00	61.40	38.86	212.67	47.87	22.5	1.73
B. gymnorrhiza	309.67	134.85	63.38	285.33	65.75	30.87	2.05
C. tagal	162.67	117.88	55.40	142.67	20.94	9.84	5.63
S. alba	229.00	135.04	63.47	183.00	24.01	11.29	5.62
A. alba	163.67.	15.01	7.06	125.33	22.07	10.37	0.68
L. racemosa	201.00	199.72	93.87	196.00	20.97	9.86	9.52
X. moluccensis	123.33	45.38	21.33	104.67	19.48	9.15	2.33
P. acidula	134.00	0.00	0.00	126.00	11.3	5.31	0.00

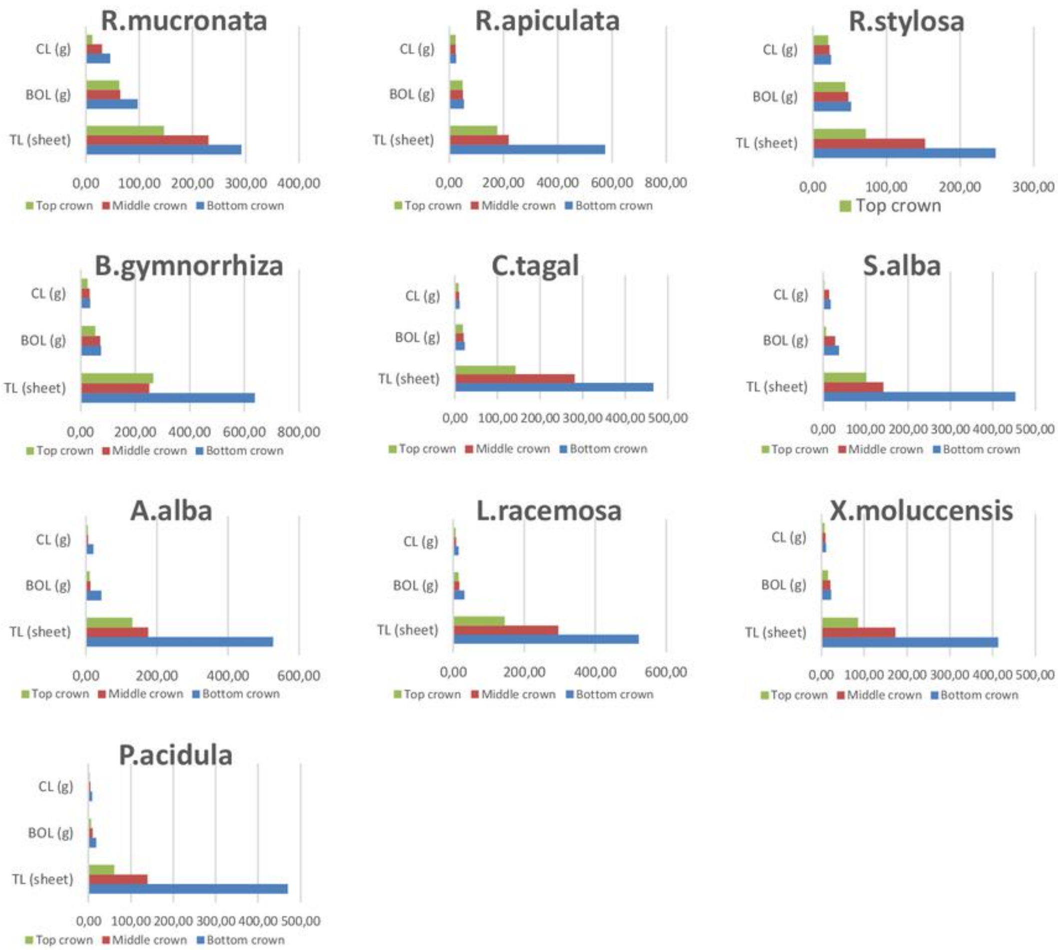
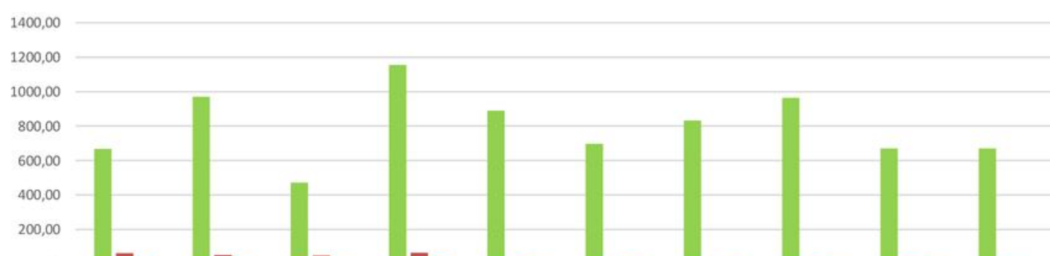


Figure 2. The distribution of total leaves (TL) (sheet), leaves biomass (BO_L) (g), and leaves carbon (C_L) (g)



	R.mucronata	R.apiculata	R.stylosa	B.gymnorrhiza	C.tagal	S.alba	A.alba	L.racemosa	X.moluccensis	P.acidula
TL (sheet)	668,00	970,23	471,90	1154,23	889,40	696,23	831,77	963,03	670,67	670,17
BOL (g)	62,08	51,12	47,87	65,75	20,94	24,01	22,07	20,97	19,48	11,3
CL (g)	29,18	24,03	22,5	30,87	9,84	11,29	10,37	9,86	9,15	5,31

Figure 3. Comparison of total leaves (TL) (sheet), leaves biomass (BO_L)(g), and leaves carbon (C_L)(g)

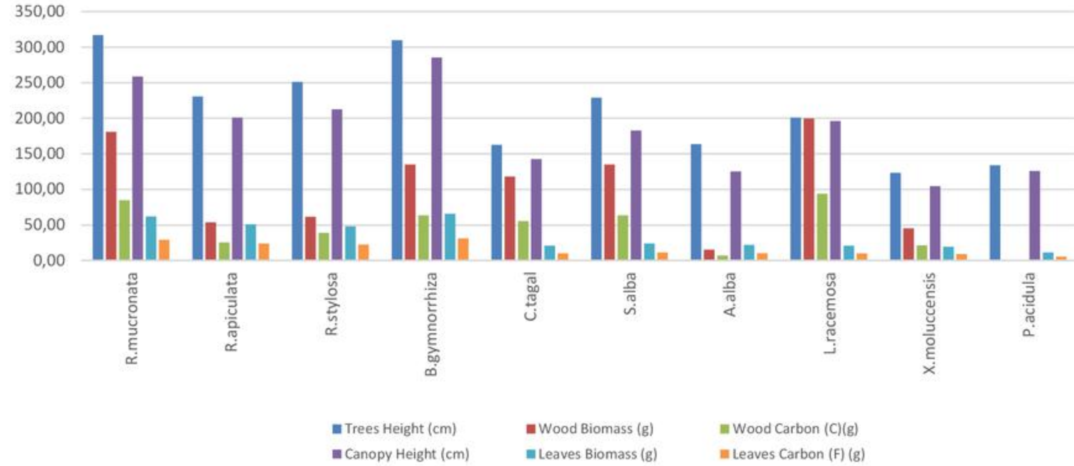


Figure 5. The comparison of trees height, wood biomass, wood carbon, and crown thickness, leaves biomass, leaves carbon

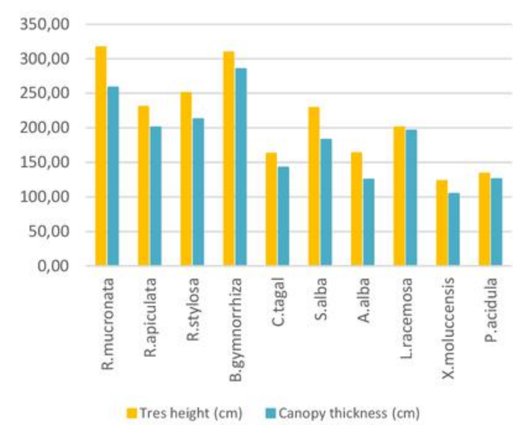


Figure 4. The comparison of tree height and crown thickness

Discussion

The relationship between the total amount of leaves and tree height in ten mangrove species showed that each species still at the leaf increasing phase. In the leaf increasing phase, tree height was followed by the total amount of leaves that formed crown layers at the top, middle and bottom part of each tree. In each species, the total amount of leaves did not constant, but continues to grow as seen in Figure 1 with regressions that evaluated positive value as shown in Table 2. This condition possibly was caused by the tree age of the species, because these trees were still young (approximately about 3 years of age), and also perhaps due to the land conditions that were poor, dominated by the texture of sandy soil. Moreover, upper layer of soil did not yet form a layer with low total density of trees at 16 species in a plot size of 20 m x 20 m.

Moller (1947) argued that leaves biomass would increase gradually with age. Kittredge (1944) also proposed that the leaves biomass increase with age and begins to be constant at 60-90 years of age. Hatinya et al. (1966) stated that leaves biomass increase with increasing of site index. In general, high leaves biomass is found in a good site condition.

The total amount of leaves varied from species. The larger or smaller the leaf weight in each species depends on the specific size of the leaf area, the larger the specific leaf area depends on the leaf area and the leaf weight of each tree species as shown in Table 3 and 4. Table 4 indicated that the *Rhizophora apiculata* showed the highest specific leaf area among others, namely 391.765 cm^2/g because it had the highest leaf area (3.33 cm^2) high with leaf weight only 0.0085 g. Likewise, *P. acidula* had leaf area of 1.24 cm^2 with the leaf weight of 0.0610 g showing a smallest specific leaf area of about 20.328 cm^2/g.

Horn (1971) divides into two types of adaptive crown that affect the development of the crown, the first development is a multilayer leaf distribution type and the second is a monolayer type which is a leaf development character formed from the overlap of young leaves on an open and closed canopy layer. In the leaf-increasing phase type, the evergreen species have a multi-layer leaf distribution (Horn 1971). It is predicted that the number of leaves will be greater than the type of mono-layer species. In addition, the distribution of vertical leaves can be calculated by the difference in leaf number on each layer of the tree crown.

The shape of the tree crown is attributed of the development of the shoots at the tip of tree as well as that the branch buds, which can be seen in the vertical distribution of the leaves and organs supporting the stem and tree branches. Waller and Steingraeber (1986), found that the adaptive architecture of tree form collective response of modular unit in the plants. The leaves are concentrated in the horizontal layer where each leaf effectively spreads and occupies the gap, to obtain sunlight. It appears that all mangrove species used as samples are concentrated in the multi-layer of the crown. The thickness of the crown is higher than the mono-layer type species.

The ratio between the amount of leaf carbon (F) and wood carbon (C) increases with tree height. Givnish (1982) found that the proportion of organs support the number of leaves such as stems, branches, and twigs is increasing very rapidly as the growth of tree height increases. The resulting net production is not only from the average of photosynthesis and respiration per unit of biomass, but also are influenced by the number of leaves to support non-photosynthesis organ of stem biomass, branches and twigs of trees. Dry weight of leaves as photosynthesis organ varies within the ratio of leaf weight and leaf area. As a result, the dry weight of the material produced during the growing season is dependent on the amount of dry weight difference occurring at the beginning of the growing season, namely on average photosynthesis and respiration results, distribution of new photosynthesis organ on different types of leaf distribution, specific leaf area and mean difference of dead organ which cause loss weight.

In conclusion, the research on the adaptation of tree architecture in mangrove forests is still very limited, but has been widely used both in tropical forests and in subtropical forest areas. The results showed that the relationship between tree height and number in leaves of ten mangrove species was positive with the value of (r) regression varying from the smallest value (R^2 = 0.6353) owned by *C. tagal* and the highest value (R^2 = 0.9704) by *Sonneratia alba*. It can be concluded that the total number of leaves per tree is still relatively increased with the increase of tree height from the smallest tree to the highest tree and still in the leaf increasing phase. The total number of leaves varies within each species between 471.90 sheets for *Rhizophora stylosa* and 1154.23 sheets for the *B. gymnorrhiza* species. Comparison of the number of leaves, leaves biomass, and leaves carbon shows the same distribution, starting at the top of the crown, to the middle and bottom, shows the development of crown units represented the increasing phase of either for each species, and can be classified into multilayer leaf distribution types.

The amount of leaf biomass and leaf carbon content in each species depends on leaf area (cm^2), leaf weight (g/sheet) and specific leaf area. *R. apiculata* leaf showing the largest value of specific leaf area, is 391.765 cm^2/g and the smallest at *P. acidula* with the value of 20.238 cm^2/g. The ratio between photosynthetic organ and non-photosynthetic organ is influenced by the biomass productivity of carbon leaves per leaf unit in each species. This ratio creates a continuous leaf increasing phase, and each species has a variable C/F ratio, the largest lies in *Lumnitzera racemosa* with C/F is 9.52, and the lowest in *Avicennia alba* with C/F is 0.68. This means that the greater the value of C/F, leaf unit or leaf carbon can form larger stems of trees and vice versa.

ACKNOWLEDGEMENTS

We thank the International Seminar committee of the Society for Indonesian Biodiversity, which has given us the opportunity to attend in this seminar and also thank the Head of Climate Change Mitigation and Forest Fire and Land Region of Java, Bali, and Nusa Tenggara that has assisted us in providing useful information.

REFERENCES

Ardhana IPG, Takeda H, Sakimoto M, Tsutsumi T. 1988. The vertical foliage distributions of six understory tree species in a Chamaecyparis obtusa Endl. Forest. Structure and Function Trees. Springer Verlag, Berlin.

Camacho LD, Gevana DT, Carandang AP, Camacho SC, Combalicer EA, Rebugio LL, Youn TC. 2011. Tree biomas and carbon stock of a community-managed mangrove forest in Bohol, Philippines. For Sci Technol 7 (4): 161-167.

Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Folster H, Fromard F, Higuchi N, Kira T, Lescure J-P, Nelson BW, Ogawa H, Puig H, Riera B, Yamakura T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145 (1): 87-99.

Chazdon RL. 1985. Leaf display, canopy structure and light interception of two understory palm species. Am J Bot 72: 1493-1502

Chazdon RL. 1986. The cost of leaf support in understory palms. Economy versus safety. Am Nat 127: 9-30

Daryadi L, Meulenhoff LMW, Soediono SY, Soemawidjaja U, al-Rasyid H, Silitonga T, Wiroatmodjo P, Martadiwangsa ES, Soekandi, Madyana T, Mardyono, Baddrudin TA, Soeparmo, Kadir K, Djokosoetarmo, Sidabutar M. 1976. Vademecum Kehutanan Indonesia. Direktorat Jenderal Kehutanan, Departemen Pertanian, Jakarta. [Indonesian]

Fatoyinbo TE, Simard M. 2013. Height and biomass of mangroves in Africa from ICESat/GLAS and SRTM. Intl J Rem Sens 34 (2): 668-681.

Givnish TJ. 1982. On the adaptive significance of leaf height in forest herbs. Am Nat 20: 353-381

Hatinya K, Tochiaki K, Narita T. 1966. Analysis of growth in natural forests of *Pinus densiflora*: relationships between site quality and growth. Trans 76th Mtg Jap For Soc (1965): 161-162.

Horn HS. 1971. The adaptive geometry of trees. Princeton University Press, Princeton, USA.

ITTO. 2013. Penyusunan baseline data pengelolaan ekosistem mangrove di Pulau Bintan. ITTO Project RED-PD 064/11 Rev. 2 (F). Direktorat Jenderal Bina Pengelolaan Daerah Aliran Sungai dan Perhutanan Sosial, Kementerian Kehutanan, Jakarta. [Indonesian]

Kittredge, 1944. Estimation of the amount of foliage of trees and stands. Journal forestry. 42:905-912

Moller CM. 1947. The effect of thinning, age, and site on foliage, increment, and loss of dry matter. Journal of forestry. 45:393-404

Nicola A, Pickett STA. 1983. The adaptive architecture of shrub canopies: leaf display and biomass allocation in relation to light environment. New Phytol 93: 301-310

Njana MA, Zahabu E, Malimbwi RE. 2017. Carbon stocks and productivity of mangrove forests in Tanzania. Southern Forests. DOI: 10.2989/20702620.2017.1334314

Sahu SC, Kumar M, Ravindranath NH. 2016. Carbon stock in natural and planted mangrove forests of Mahanadi mangrove Wetland, East Coast of India. Curr Sci 110 (12): 2334-2341.

Schulze ED, Kuppers M, Matyssek R. 1986. The role of carbon balance and branching pattern in the growth of woody species. In: Givinish TJ (ed) On the Economy of Plant Form and Function. Cambridge University Press, New York.

Sitoe AA, Mandlate LJC, Guedes BS. 2014. Biomass and carbon stocks of Sofala Bay Mangrove Forest. Forests 5 (8): 1967-1981.

SNI. 2011. SNI No. 7724: 2011 Pengukuran dan penghitungan cadangan karbon pengukuran lapangan Untuk penaksiran cadangan karbon hutan (Ground-based forest carbon accounting). Badan Standarisasi Nasional, Jakarta. [Indonesian]

Taberima S, Nugroho YD, Murdiyarso D. 2014. The distribution of carbon stock in selected. mangrove ecosystem of Wetlands Papua: Bintuni, Teminabuan, and Timika, Eastem Indonesia. Intemasional Conference on Chemical, Environment & Biological Sciences. Kuala Lumpur, Malaysia.
Waller DM, Steingraeber DA. 1986. Branching and modular growth. In: Jackson JBC, Buss LW, Cook PE (eds.) Population Biology and Evolution of Clonal Organisms. Yale University Press, New Haven, USA.
Zanne AE, Lopez-Gonzalez G, Coomes DA, Ilic J, Jansen S, Lewis SL, Miller RB, Swenson NG, Wiemann MC, Chave J. 2009. Data from: towards a worldwide wood economics spectrum. Dryad Digital Repository 2009. DOI: 10.5061/dryad.234.

The distribution of vertical leaves and leaves biomass on ten mangrove species at Ngurah Rai Forest Park, Denpasar, Bali, Indonesia

ORIGINALITY REPORT

12%	10%	9%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Roel J. W. Brienen. "Attaining the canopy in dry and moist tropical forests: strong differences in tree growth trajectories reflect variation in growing conditions", Oecologia, 12/24/2009 Publication	1%
2	Dooley, Edith M., and Diana L. Six. "Severe White Pine Blister Rust Infection in Whitebark Pine Alters Mountain Pine Beetle (Coleoptera: Curculionidae) Attack Density, Emergence Rate, and Body Size", Environmental Entomology, 2015. Publication	1%
3	www.synergos.org Internet Source	1%
4	www.nrcresearchpress.com Internet Source	1%
5	Submitted to Oklahoma State University Student Paper	1%

6	Koji Kawamura. "Light environment and crown architecture of two temperate *Vaccinium* species: inherent growth rules versus degree of plasticity in light response", Canadian Journal of Botany, 10/2002 Publication	1%
7	M. A. DAMASCOS. "Bud Composition, Branching Patterns and Leaf Phenology in Cerrado Woody Species", Annals of Botany, 08/26/2005 Publication	1%
8	Abino, Azyleah C., Jose Alan A. Castillo, and Young Jin Lee. "Assessment of species diversity, biomass and carbon sequestration potential of a natural mangrove stand in Samar, the Philippines", Forest Science and Technology, 2014. Publication	1%
9	HIROAKI ISHII. "Effects of the spatial arrangement of aerial stems and current-year shoots on the demography and growth of Hydrangea hirta in a light-limited environment", New Phytologist, 7/1997 Publication	<1%
10	www.sisef.it Internet Source	<1%
11	ejournal.forda-mof.org	

	Internet Source		<1%
12	link.springer.com Internet Source		<1%
13	Submitted to Heriot-Watt University Student Paper		<1%
14	Submitted to University of Liverpool Student Paper		<1%
15	iicbe.org Internet Source		<1%
16	hal.archives-ouvertes.fr Internet Source		<1%
17	www.esapubs.org Internet Source		<1%
18	Submitted to University of Queensland Student Paper		<1%
19	"Threats to Mangrove Forests", Springer Nature, 2018 Publication		<1%
20	ppid.menlhk.go.id Internet Source		<1%
21	www.publish.csiro.au Internet Source		<1%

Lee, Kent D., and Steve Hubbard. "Trees",

22	Undergraduate Topics in Computer Science, 2015. Publication	<1%
23	Webb, Edward L., Martin van de Bult, Siaifoi Fa'aumu, Rachel C. Webb, Ailao Tualaulelei, and Luis R. Carrasco. "Factors Affecting Tropical Tree Damage and Survival after Catastrophic Wind Disturbance", Biotropica, 2014. Publication	<1%
24	travelmoka.blogspot.com Internet Source	<1%
25	www.kotapermai.com.my Internet Source	<1%
26	Submitted to University of Nottingham Student Paper	<1%
27	jurnalmapeki.biomaterial-lipi.org Internet Source	<1%
28	Mortensen, L.M.. "Effects of CO"2 enrichment and different day/ night temperature combinations on growth and flowering of Rosa L. and Kalanchoe blossfeldiana v. poelln.", Scientia Horticulturae, 199207 Publication	<1%
29	es.scribd.com Internet Source	<1%

30	library.umaine.edu Internet Source	<1%
31	Robert W. Pearcy. "Crown architecture in sun and shade environments: assessing function and trade-offs with a three-dimensional simulation model", New Phytologist, 6/2005 Publication	<1%
32	krishikosh.egranth.ac.in Internet Source	<1%
33	docplayer.net Internet Source	<1%
34	epdf.tips Internet Source	<1%
35	www.mdpi.com Internet Source	<1%
36	www.ots.duke.edu Internet Source	<1%
37	portalgaruda.ilkom.unsri.ac.id Internet Source	<1%
38	aob.oxfordjournals.org Internet Source	<1%
39	Zambia country profile Monitoring reporting and verification for REDD+, 2014. Publication	<1%

40 Usha R. Palaniswamy, Richard J. McAvoy, Bernard B. Bible, James D. Stuart. " Ontogenic Variations of Ascorbic Acid and Phenethyl Isothiocyanate Concentrations in Watercress (R.Br.) Leaves ", Journal of Agricultural and Food Chemistry, 2003
Publication
<1%

41 Cheng Hu Chao. "Fusion boundary structures in a laser welded duplex Fe-Mn-Al-C alloy", Journal of Materials Science, 1992
Publication
<1%

42 Marco A Njana, Eliakimu Zahabu, Rogers E Malimbwi. "Carbon stocks and productivity of mangrove forests in Tanzania", Southern Forests: a Journal of Forest Science, 2017
Publication
<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		