Stem Carbon Dioxide Efflux of Lignophytes Exceeds That of Cycads and Arborescent Monocots

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Abstract: Tree stem CO₂ efflux (Es) can be substantial and the factors controlling ecosystem-level Es are required to fully understand the carbon cycle and construct models that predict atmospheric CO₂ dynamics. The majority of Es studies used woody lignophyte trees as the model species. Applying these lignophyte data to represent all tree forms can be inaccurate. The Es of 318 arborescent species was quantified in a common garden setting and the results were sorted into four stem growth forms: cycads, palms, monocot trees that were not palms, and woody lignophyte trees. The woody trees were comprised of gymnosperm and eudicot species. The Es did not differ among the cycads, palms, and non-palm monocots. Lignophyte trees exhibited Es that was 40% greater than that of the other stem growth forms. The Es of lignophyte gymnosperm trees was similar to that of lignophyte eudicot trees. This extensive species survey indicates that the Es from lignophyte tree species do not align with the Es from other tree growth forms. Use of Es estimates from the literature can be inaccurate for understanding the carbon cycle in tropical forests, which contain numerous non-lignophyte tree species.

Keywords: conservation physiology; secondary cambium; stem respiration

1. Introduction

The efflux of carbon dioxide (CO₂) from tree stem surfaces (Es) has been extensively studied to answer various questions and more fully understand the global carbon cycle [1,2]. As with many aspects of biology research, the Es literature is biased toward one subset of biodiversity. Most case studies of tree Es have focused exclusively on lignophyte species with stems comprised mostly of wood constructed by true bifacial secondary cambium. This expansive literature contains only a few examples in which pachycaulous tree species with stems devoid of bifacial secondary cambium were represented [3–6].

A major contributor to Es is stem tissue respiration. However, numerous interacting factors coalesce to define Es in space and time. For example, CO₂ from root respiration can be transported to stems by way of xylem, and this CO₂ can exit xylem within stems to increase the Es above that of stem tissue respiration [7,8]. This transported CO₂ is under the influence of diel variations in sap flow [9,10]. The movement of CO₂ from the internal tissues to stem surfaces can also be under the control of temporal storage or re-fixation [11]. These and other interacting factors can cause the Es to be heavily influenced by CO₂ that was respired from tissues that are distant from the site of efflux [12].

A recent study designed to understand the diel patterns of Es for arborescent cycads, monocots, and lignophytes [6] included only six species of each growth form. Other studies that compared different stem tissue anatomy and its influence in Es were restricted to lignophyte species [13–15]. An extensive survey to compare the Es of trees with disparate stem growth forms has not been conducted to date in a single forest or garden. I hypothesized that Es from an extensive range of tree species would sort into significantly different groups, based on stem design. The objective of this study was to use the large living collection in a common garden setting to compare the Es of four growth forms used to design and construct tree stems.
2. Materials and Methods

This study was conducted at Nong Nooch Tropical Botanical Garden in Sattahip, Thailand. The dates of measurements were 8–15 July 2019. In this setting and this time of year, the Es of non-lignophyte trees was not influenced by the time of day, but the lignophyte trees exhibited greater Es during midday [6]. Therefore, the measurements for this extensive species survey were restricted to the hours of 900–1500 h on each day of measurement.

A total of 99 cycad species were included (Table A1). There were 96 lignophyte species included (Table A2). The arborescent monocot species were separated into two groups. A total of 17 arborescent monocot taxa that were not palm species were included (Table A3). Finally, there were 106 palm species in the study (Table A4).

The Es was measured, as previously described [4–6]. Vigorous trees with no obvious wounds or decay on the stems were selected. A CIRAS EGM-4 analyzer fitted with a SRC-1 close system chamber (PP Systems, Amesbury, MA, USA) was used to quantify the Es from the stem surfaces. The chamber was secured using modeling clay as the sealant at a stem height of 30–40 cm above the root collar. The EGM-4 recorded the air temperature, and the chamber’s increase in CO\textsubscript{2} concentration above ambient was quantified after a 2 min period. The change in CO\textsubscript{2} concentration was used to calculate the flux by dividing by area and time. Three periods of efflux were recorded at different radial locations for each sampling period for each tree.

The stem surface temperature was measured with an infrared thermometer (Milwaukee Model 2267-20, Milwaukee Tool, Brookfield, WI, USA). The relative humidity was determined with a sling psychrometer every hour during the periods of measurements. The stem diameter at the height of measurements and total stem height were measured for each tree.

Two sampling periods were applied to each species. For taxa with more than one large tree, this included two trees. For taxa with a single large tree, the two samples were from the same tree but separated by at least three days. The data were sorted according to four stem growth forms: cycad species, palm species, arborescent non-palm monocot species, and lignophyte species. The data were subjected to ANOVA using the PROC MIXED model (SAS Institute, Cary, NC, USA) with unequal replications. There were 636 observations in the data set, two per species. The two observations were treated as subsamples in the analysis. The means separation was conducted by Tukey’s HSD test.

3. Results and Discussion

The cycad trees were represented by 53 Cycadaceae and 46 Zamiaceae species (Table A1). The stem circumference ranged from 51–169 cm with a mean of 96 cm. The mean stem temperature was 31.8 °C and the concomitant mean air temperature was 32.6 °C. Individual Es measurements ranged from 0.5–6.2 μmol·m\textsuperscript{−2}·s\textsuperscript{−1}. The lignophyte trees were represented by 34 families (Table A2). The stem circumference ranged from 51–156 cm with a mean of 84 cm. The mean stem temperature was 31.3 °C and concomitant mean air temperature was 32.0 °C. Individual Es measurements ranged from 0.2–7.6 μmol·m\textsuperscript{−2}·s\textsuperscript{−1}. The arborescent non-palm monocot species, and lignophyte species. The data were subjected to ANOVA using the PROC MIXED model (SAS Institute, Cary, NC, USA) with unequal replications. There were 636 observations in the data set, two per species. The two observations were treated as subsamples in the analysis. The means separation was conducted by Tukey’s HSD test.

The palm species representing the Arecaceae family exhibited a stem circumference ranging from 48–182 cm with a mean of 71 cm (Table A4). The mean stem temperature was 31.5 °C and the concomitant mean air temperature was 32.1 °C. The individual Es measurements range from 0.7–7.5 μmol·m\textsuperscript{−2}·s\textsuperscript{−1}. The relative humidity ranged from 56% to 69% and did not change substantially among the hours and dates of the study.

The stem CO\textsubscript{2} efflux differed among the four stem growth forms ($F_{3,314} = 10.64$, $p < 0.001$). The means separated into two groups, with the lignophyte species exhibiting greater Es than the other three stem growth forms (Table 1). The lignophyte trees exhibited
Es that was 40% greater than the mean of the other growth forms. No differences in the Es occurred among the cycad, palm, and non-palm monocot stem forms.

Table 1. Stem carbon dioxide efflux (µmol·m⁻²·s⁻¹) of arborescent species as influenced by the stem growth form.

| Stem Growth Form         | n  | Efflux            |
|--------------------------|----|-------------------|
| Lignophyte ¹             | 96 | 3.421 ± 0.140 a ² |
| Palm                     | 106| 2.593 ± 0.133 b   |
| Cycad                    | 99 | 2.415 ± 0.138 b   |
| Monocot (non-palm)       | 17 | 2.321 ± 0.332 b   |

¹ The lignophyte species were eudicot and gymnosperm trees that produce true wood from secondary bifacial vascular cambium. ² Growth form with the same letter not different according to Tukey’s HSD test.

Cycads and monocot trees often produce thick primary growth constructed by a primary thickening meristem, and do not possess bifacial secondary cambium to increase stem diameter at distances away from the stem tip [16–22]. For all of these trees, the peripheral tissues are ground tissue with vascular tissues embedded closer to the stem center. One of the factors that influences CO₂ efflux from a stem surface is the diffusion and conductance constraints imposed by tissues that are peripheral to tissues that serve as the greatest internal source of CO₂, such as sap flow in xylem [23]. The substantial radial distance of xylem tissues and other major sources of CO₂ from the stem surface of these pachycaulous trees can account for the greater mean Es for lignophyte trees, which has been shown herein.

Considering the prominence of these pachycaulous trees in tropical forests, the historical exclusion of them from Es studies is unfortunate. Indeed, the CO₂ derived from stem efflux can represent up to 40% of the CO₂ contributed to by vegetation [1,24]. This survey, represented by 222 pachycaulous tree species, confirms the earlier findings based on a limited number of species [6], and indicates that attempts to use the Es literature based on the lignophyte species can over-estimate the Es in regions that are represented by these tree species.

Cycads comprise the most threatened contemporary plant group [25]. Conservation physiology has emerged as a critical component of the suite of conservation strategies, because an understanding of the physiological responses of threatened organisms to their escalating biotic and abiotic threats is required for successful species recovery [26,27]. For federally listed endangered cycad species in the United States, such as *Cycas micronesica* K.D. Hill (see Table A1), understanding the physiology of the taxa is crucial for developing effective federal recovery plans [28]. Clearly, the pursuit of more cycad physiology studies will advance the nascent discipline of conservation physiology.

Future research on the Es of cycad and monocot trees will be required to fully understand the reasons that mean Es is less than the mean Es of lignophyte trees. The design of cycad stems is fairly homogeneous, with vascular cylinders inserted between the persistent living pith and cortex [29]. The design of palm stems is also fairly homogeneous with vascular bundles scattered through the ground tissue [19,22]. However, the design of the non-palm arborescent monocot tree stems is heterogeneous among the families. A closer look at this group of pachycaulous species can yield interesting findings about what endogenous factors mostly control the Es of these non-lignophyte trees.

In conclusion, the many factors that interact to control the magnitude of CO₂ efflux from tree stem surfaces are differentially expressed among various tree stem designs. The results herein suggest that the traits of stem peripheral tissues can be among the defining factors that cause the differences in Es among various tree growth forms.

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Appendix A

Table A1. List of cycad species included in the carbon dioxide efflux study. Circ = circumference, Air T = air temperature, and Stem T = surface temperature of stems.

| Species Family | Species | Family | Circ (cm) | Air T | Stem T | Sample 1 | Sample 2 |
|----------------|---------|--------|-----------|-------|--------|----------|----------|
| Zamiaceae      | Ceratozamia delucana Vázq.Torres, A.Moretti and Carvajal-Hern. | Zamiaceae | 84 | 32 | 32.9 | 2.6222 | 2.3290 |
| Zamiaceae      | Ceratozamia latifolia Miq. | Zamiaceae | 72 | 31 | 32.9 | 2.3227 | 2.0197 |
| Zamiaceae      | Ceratozamia robusta Miq. | Zamiaceae | 112 | 31 | 33.1 | 2.2501 | 1.9566 |
| Cycadaceae     | Cycas angulata R.Br. | Cycadaceae | 107 | 32 | 32.8 | 5.7745 | 5.1166 |
| Cycadaceae     | Cycas apos K.D.Hill | Cycadaceae | 76 | 33 | 32.5 | 4.3633 | 4.2288 |
| Cycadaceae     | Cycas badensis K.D.Hill | Cycadaceae | 82 | 32 | 31.1 | 1.7512 | 1.5148 |
| Cycadaceae     | Cycas beddomei Dyer | Cycadaceae | 78 | 33 | 31.7 | 1.7819 | 1.5508 |
| Cycadaceae     | Cycas bougainvilleana K.D.Hill | Cycadaceae | 65 | 32 | 31.1 | 4.1522 | 3.6103 |
| Cycadaceae     | Cycas caimensis F.Muell. | Cycadaceae | 101 | 31 | 31.4 | 2.0749 | 1.8051 |
| Cycadaceae     | Cycas campestris K.D.Hill | Cycadaceae | 93 | 32 | 30.4 | 2.4442 | 2.1251 |
| Cycadaceae     | Cycas chamaeopsis K.D.Hill | Cycadaceae | 101 | 32 | 31.8 | 1.8463 | 1.5969 |
| Cycadaceae     | Cycas changjiangensis N.Liu | Cycadaceae | 81 | 33 | 31.7 | 1.0225 | 2.2722 |
| Cycadaceae     | Cycasclinicola K.D.Hill | Cycadaceae | 87 | 33 | 31.7 | 2.0377 | 1.7805 |
| Cycadaceae     | Cycas coudisia K.D.Hill | Cycadaceae | 95 | 33 | 32.1 | 0.9089 | 1.1361 |
| Cycadaceae     | Cycas currans (J.Schust.) K.D.Hill | Cycadaceae | 103 | 32 | 30.1 | 5.1493 | 4.8000 |
| Cycadaceae     | Cycas deboeomensis Y.C.Zhong and C.J.Chen | Cycadaceae | 110 | 32 | 30.9 | 1.5203 | 1.3191 |
| Cycadaceae     | Cycas diannanensis Z.T.Guan and G.D.Tao | Cycadaceae | 84 | 33 | 32.1 | 5.6678 | 4.9231 |
| Cycadaceae     | Cycas edentata de Laub. | Cycadaceae | 68 | 32 | 29.8 | 1.9212 | 1.6663 |
| Cycadaceae     | Cycas elongata (Leandri) D.Y.Wang | Cycadaceae | 103 | 32 | 31.9 | 2.1460 | 1.7042 |
| Cycadaceae     | Cycas falcata K.D.Hill | Cycadaceae | 89 | 33 | 31.8 | 2.8403 | 1.4517 |
| Cycadaceae     | Cycas furfuracea W.Fitzg. | Cycadaceae | 108 | 34 | 34.5 | 2.5564 | 2.2217 |
| Cycadaceae     | Cycas glauca Miq. | Cycadaceae | 92 | 33 | 32.2 | 4.0045 | 3.5346 |
| Cycadaceae     | Cycas hainanensis C.J.Chen ex C.Y.Cheng, W.C.Cheng and L.K.Fu | Cycadaceae | 91 | 33 | 31.4 | 2.5496 | 2.2217 |
| Cycadaceae     | Cycas honghensis S.Y.Yang and S.L.Yang | Cycadaceae | 82 | 32 | 30.8 | 2.2847 | 2.1165 |
| Cycadaceae     | Cycas inermis Lour. | Cycadaceae | 109 | 33 | 32.1 | 6.1934 | 5.4154 |
| Cycadaceae     | Cycas jarauna (Miq.) de Laub. | Cycadaceae | 112 | 33 | 32.7 | 2.7945 | 2.4300 |
| Cycadaceae     | Cycas macrocarpa Griff. | Cycadaceae | 75 | 31 | 31.2 | 4.1164 | 3.6103 |
| Cycadaceae     | Cycas media R.Br. | Cycadaceae | 82 | 33 | 31.9 | 2.1964 | 1.8996 |
| Cycadaceae     | Cycas megacarpa K.D.Hill | Cycadaceae | 62 | 33 | 31.8 | 2.1114 | 1.8380 |
| Cycadaceae     | Cycas microsperma K.D.Hill | Cycadaceae | 62 | 33 | 32.5 | 1.3764 | 1.1992 |
| Cycadaceae     | Cycas nathorstii J.Schust. | Cycadaceae | 102 | 32 | 31.9 | 1.7446 | 1.5148 |
| Cycadaceae     | Cycas nongnoochiae K.D.Hill | Cycadaceae | 88 | 33 | 31.9 | 2.9513 | 2.5689 |
| Cycadaceae     | Cycas ophiolitica K.D.Hill | Cycadaceae | 115 | 33 | 32.1 | 1.1846 | 1.0225 |
| Cycadaceae     | Cycas pachypoda K.D.Hill | Cycadaceae | 98 | 32 | 30.8 | 4.4112 | 3.8482 |
| Cycadaceae     | Cycas papuana F.Muell. | Cycadaceae | 86 | 31 | 30.7 | 5.3312 | 4.6517 |
| Cycadaceae     | Cycas pectinata Buch.-Ham. | Cycadaceae | 93 | 32 | 33.4 | 2.0547 | 1.7805 |
| Cycadaceae     | Cycas petrae A.Lindstr. and K.D.Hill | Cycadaceae | 69 | 33 | 32.1 | 1.7965 | 2.3353 |
| Cycadaceae     | Cycas platyphylla K.D.Hill | Cycadaceae | 116 | 33 | 31.7 | 0.6817 | 1.5905 |
| Cycadaceae     | Cycas prainburiensis Yang, Tang, Hill and Vatcharakorn | Cycadaceae | 78 | 33 | 32.5 | 1.5115 | 1.3210 |
| Cycadaceae     | Cycas revoluta Thunb. | Cycadaceae | 85 | 32 | 32.8 | 2.2223 | 1.9314 |
| Species Family | Circ (cm) | Air T | Stem T | Sample 1 | Sample 2 |
|----------------|-----------|-------|--------|----------|----------|
| Cycas rumianniana Porte ex Regel | Cycadaceae | 65 | 33 | 33.1 | 3.7784 | 3.2821 |
| Cycas rumphii Miq. | Cycadaceae | 84 | 30 | 32.1 | 4.0561 | 3.5346 |
| Cycas seemannii A.Br. | Cycadaceae | 63 | 32 | 31.1 | 3.0296 | 2.1523 |
| Cycas semoz K.D.Hill | Cycadaceae | 84 | 33 | 30.2 | 3.4865 | 3.0296 |
| Cycas shanyaensis G.A.Fu | Cycadaceae | 68 | 32 | 32.1 | 2.4690 | 3.0296 |
| Cycas siamensis Miq. | Cycadaceae | 79 | 32 | 31.9 | 3.4431 | 2.9867 |
| Cycas silvestris K.D.Hill | Cycadaceae | 69 | 33 | 32.2 | 1.6679 | 1.4517 |
| Cycas sphaerica Roxb. | Cycadaceae | 92 | 33 | 32.2 | 3.4155 | 2.9867 |
| Cycas taitungensis Shen, Hill, Tsou and Chen | Cycadaceae | 83 | 32 | 31.8 | 4.4478 | 3.8968 |
| Cycas tansachana K.D.Hill and S.L.Yang | Cycadaceae | 113 | 33 | 31.8 | 1.1864 | 1.0099 |
| Cycas thouarsii R.Br. | Cycadaceae | 82 | 31 | 30.9 | 1.1968 | 1.0225 |
| Cycas tropophylla K.D.Hill and P.K.Lôc | Cycadaceae | 94 | 33 | 32.1 | 2.0312 | 1.7673 |
| Cycas tuckeri K.D.Hill | Cycadaceae | 95 | 32 | 30.8 | 1.7157 | 1.4933 |
| Cycas wadei Merr. | Cycadaceae | 83 | 32 | 31.3 | 2.1113 | 1.8380 |
| Cycas yorkiana K.D.Hill | Cycadaceae | 94 | 33 | 32.1 | 2.1564 | 1.8746 |
| Cycas zeylanica (J.Schust.) A.Lindstr. and K.D.Hill | Cycadaceae | 78 | 33 | 30.8 | 2.3312 | 2.0103 |
| Dioon argenteum Gregory, Chemnick, Salas-Morales and Vovides | Zamiaceae | 93 | 33 | 31.1 | 4.9455 | 4.4308 |
| Dioon caputoi De Luca, Sabato and Vázq.Torres | Zamiaceae | 91 | 32 | 34.8 | 2.4837 | 2.1523 |
| Dioon edule Lindl. | Zamiaceae | 155 | 32 | 33.1 | 3.7795 | 3.2821 |
| Dioon mejiae Standl. and L.O. Williams | Zamiaceae | 98 | 33 | 31.6 | 1.9594 | 1.7042 |
| Dioon spinulosum Dyer ex Eichl. | Zamiaceae | 91 | 33 | 32.2 | 2.2561 | 1.9566 |
| Encephalartos aemulans Vorster | Zamiaceae | 138 | 33 | 31.9 | 4.4466 | 3.9976 |
| Encephalartos altensteinii Lehmi. | Zamiaceae | 116 | 34 | 32.2 | 2.2504 | 2.4679 |
| Encephalartos arenarius R.A.Dyer | Zamiaceae | 97 | 33 | 32.2 | 1.4495 | 1.5905 |
| Encephalartos bulbatus Melville | Zamiaceae | 125 | 33 | 31.7 | 1.0569 | 1.1614 |
| Encephalartos chimanimaniensis R.A.Dyer and I.Verd. | Zamiaceae | 121 | 33 | 31.8 | 1.5948 | 1.7420 |
| Encephalartos concinnus R.A.Dyer and Verdoorn | Zamiaceae | 114 | 33 | 32.1 | 4.9765 | 5.4465 |
| Encephalartos dyerianus Lavranos and D.L.Goode | Zamiaceae | 124 | 34 | 32.9 | 3.5004 | 3.8501 |
| Encephalartos equatorialis P.J.H.Hurter | Zamiaceae | 127 | 34 | 32.9 | 1.7764 | 1.9314 |
| Encephalartos eugene-maraisii Verg. | Zamiaceae | 116 | 33 | 32.1 | 2.2465 | 2.4679 |
| Encephalartos inopinus R.A.Dyer and I.Verd. | Zamiaceae | 121 | 33 | 32.2 | 2.3611 | 2.5878 |
| Encephalartos lebomboensis I.Verd. | Zamiaceae | 97 | 33 | 32.3 | 1.6564 | 1.8146 |
| Encephalartos macrostrobilus Dyer ex Eichl. | Zamiaceae | 111 | 33 | 32.2 | 0.8645 | 0.9089 |
| Encephalartos manikensis (Gilliland) Gilliland | Zamiaceae | 125 | 34 | 32.8 | 1.7946 | 1.9566 |
| Encephalartos manikensis (Gilliland) Gilliland | Zamiaceae | 133 | 33 | 31.7 | 1.5946 | 1.7420 |
| Encephalartos natalensis R.A.Dyer and I.Verd. | Zamiaceae | 108 | 33 | 32.1 | 2.9764 | 3.2663 |
| Encephalartos paucidentatus Stapf and Burtt Davy | Zamiaceae | 134 | 33 | 32.2 | 2.3331 | 2.5562 |
| Encephalartos princeps R.A.Dyer | Zamiaceae | 109 | 34 | 32.9 | 1.1915 | 1.3065 |
| Encephalartos pterogonus R.A.Dyer and I.Verd. | Zamiaceae | 120 | 33 | 32.5 | 1.7764 | 1.9314 |
| Encephalartos sclavoii De Luca, D.W.Stev. and A.Moretti | Zamiaceae | 119 | 33 | 32.8 | 2.0645 | 1.8947 |
| Encephalartos septentrionalis Schweinf. | Zamiaceae | 107 | 32 | 30.9 | 0.8465 | 0.8710 |
| Encephalartos septentrionalis Schweinf. | Zamiaceae | 119 | 34 | 32.9 | 1.6694 | 3.7239 |
| Encephalartos secticus Vorster | Zamiaceae | 124 | 33 | 32.1 | 3.6915 | 4.0647 |
| Encephalartos silvestris Melville | Zamiaceae | 128 | 33 | 31.2 | 4.5121 | 4.9357 |
| Encephalartos whiteicockii P.J.H.Hurter | Zamiaceae | 163 | 32 | 31.1 | 2.7154 | 2.9865 |
| Lepidozamia hopei (W.Hill) Regel | Zamiaceae | 64 | 32 | 29.1 | 1.4896 | 1.2623 |
| Lepidozamia peroffskyana Regel | Zamiaceae | 92 | 33 | 33.8 | 1.6765 | 1.8304 |
### Table A1. Cont.

| Species                     | Family            | Circ (cm) | Air T | Stem T | Sample 1  | Sample 2  |
|-----------------------------|-------------------|-----------|-------|--------|-----------|-----------|
| Macrozamia moorei F.Muell. | Zamiaceae         | 169       | 32    | 32.7   | 1.8686    | 1.6663    |
| Microcycas calocoma (Miq.) A.DC. | Zamiaceae       | 91        | 32    | 32.1   | 2.0644    | 1.8304    |
| Zamia eleganssima Schutzman, Vovides and R.S.Adams | Zamiaceae     | 51        | 33    | 30.9   | 1.3312    | 1.4517    |
| Zamia furfuracea L.f.      | Zamiaceae         | 91        | 33    | 32.1   | 1.7154    | 1.8746    |
| Zamia gentryi Dodson       | Zamiaceae         | 63        | 33    | 30.5   | 2.0105    | 2.1999    |
| Zamia imperialis A.S.Taylor, J.L.Haynes and Holzman | Zamiaceae     | 59        | 32    | 31.1   | 1.3866    | 1.5148    |
| Zamia lindenii Regel ex André | Zamiaceae      | 78        | 30    | 29.9   | 2.0166    | 2.1998    |
| Zamia obliqua A.Braun      | Zamiaceae         | 51        | 32    | 30.2   | 2.7626    | 2.9965    |
| Zamia skinneri Warsc.      | Zamiaceae         | 58        | 32    | 30.2   | 2.3465    | 2.5765    |

### Table A2. List of the lignophyte species included in the carbon dioxide efflux study. Circ = circumference, Air T = air temperature, and Stem T = surface temperature of stems.

| Species                              | Family                | Circ (cm) | Air T | Stem T | Sample 1  | Sample 2  |
|--------------------------------------|-----------------------|-----------|-------|--------|-----------|-----------|
| Acacia auriculiformis A.Cunn. Ex Berth. | Fabaceae             | 92        | 32    | 29.3   | 3.5566    | 3.7944    |
| Adansonia digitata L.                | Malvaceae             | 71        | 31    | 31.4   | 3.9465    | 3.5546    |
| Adansonia madagascariensis Baill.    | Malvaceae             | 69        | 33    | 32.3   | 2.0566    | 1.8304    |
| Afrocarpus gracilior (Pilg.) C.N. Page | Podocarpaceae        | 72        | 32    | 31.3   | 6.4465    | 6.3748    |
| Agathis dammara (Lamb.) Rich.        | Araucariaceae         | 85        | 33    | 32.2   | 2.3465    | 2.5698    |
| Agathis moorei (Lind.) Mast.         | Araucariaceae         | 52        | 33    | 30.9   | 1.3255    | 1.8304    |
| Agathis robusta (C.Moore ex F.Muell.) Bailey | Araucariaceae    | 55        | 32    | 30.9   | 1.7198    | 1.8935    |
| Albizia saman (Jacq.) Merr.          | Fabaceae              | 156       | 32    | 30.6   | 1.2765    | 1.3886    |
| Angheria nobilis Wall.               | Fabaceae              | 68        | 32    | 31.4   | 2.1894    | 1.9566    |
| Annona squamosa L.                   | Annonaceae            | 62        | 31    | 30.8   | 1.6768    | 1.8746    |
| Araucaria bidwillii Hook.            | Araucariaceae         | 91        | 32    | 31.2   | 5.0032    | 4.4813    |
| Araucaria columnaris J.R.Forst. Hook. | Araucariaceae        | 69        | 30    | 30.2   | 6.2264    | 5.6237    |
| Araucaria cunninghamii Mudie         | Araucariaceae         | 58        | 31    | 29.4   | 2.3631    | 2.0829    |
| Araucaria heterophylla (Salisb.) Franco | Araucariaceae       | 96        | 32    | 33.2   | 2.8403    | 2.7771    |
| Araucaria luxurians (Brong. and Grisb.) de Laub. | Araucariaceae | 64        | 31    | 30.1   | 6.0021    | 5.4281    |
| Araucaria montana Brong. and Gris    | Araucariaceae         | 54        | 32    | 31.8   | 2.9034    | 2.6643    |
| Araucaria nemorosa de Laub.          | Araucariaceae         | 93        | 33    | 31.8   | 2.0829    | 2.0197    |
| Artocarpus altisas (Parkinson) Fosberg | Moraceae             | 88        | 33    | 32.1   | 3.6625    | 3.9986    |
| Artocarpus heterophyllus Lam.        | Moraceae              | 74        | 31    | 30.8   | 2.4689    | 2.7140    |
| Averrhoa bilimbi L.                  | Oxalidaceae           | 72        | 33    | 32.3   | 4.2165    | 4.6647    |
| Averrhoa carambola L.                | Oxalidaceae           | 69        | 31    | 30.1   | 4.4465    | 3.9865    |
| Bougainvillea sp. Comm. Ex Juss.     | Nyctaginaceae         | 51        | 33    | 32.1   | 1.9955    | 2.1133    |
| Brachychiton acerifolius (A.Cunn ex G.Don) | Malvaceae           | 53        | 31    | 31.7   | 2.2566    | 2.0134    |
| Brachychiton rupestris (T.Mitch. Ex Lindl.) | Malvaceae         | 54        | 30    | 30.3   | 4.4656    | 4.0269    |
| K.Schum.                             | Burseraceae           | 51        | 32    | 30.8   | 0.8119    | 0.9026    |
| Callistemon vinimalis (Sol. Ex Gaertn.) G.Don | Myrtaceae           | 77        | 30    | 30.7   | 6.0022    | 5.4154    |
| Callistris baileyi C.T. White       | Cupressaceae          | 59        | 31    | 30.8   | 2.6444    | 2.3984    |
| Calophyllum sil Lauterb.             | Clusiaceae            | 103       | 30    | 30.9   | 3.3186    | 3.0107    |
| Cananga odorata (Lam.) Hook.f. and Thomson | Annonaceae          | 121       | 32    | 31.1   | 4.4212    | 4.8766    |
| Casuarina equisetifolia L.           | Casuarinaceae         | 102       | 33    | 33.4   | 3.5564    | 3.8965    |
| Cavanilles hylocleiton Ulbr.         | Malvaceae             | 111       | 33    | 32.8   | 2.8845    | 2.5562    |
| Cecropia obtusifolia Bertol.         | Urticaceae            | 88        | 31    | 30.3   | 5.1114    | 4.6012    |
| Cecropia peltata L.                  | Urticaceae            | 113       | 32    | 31.6   | 3.6266    | 3.2265    |
| Ceiba pentandra (L.) Gaertn.         | Malvaceae             | 123       | 33    | 31.9   | 4.3489    | 3.9196    |
| Clusia rosea Jacq.                  | Clusiaceae            | 61        | 36    | 31.3   | 3.1153    | 3.5642    |
| Delonix decaryi (R.Vig.) Capuron     | Fabaceae              | 82        | 32    | 31.7   | 1.3349    | 1.1992    |
Table A2. Cont.

| Species | Family                  | Circ (cm) | Air T | Stem T | Sample 1   | Sample 2   |
|---------|-------------------------|-----------|-------|--------|------------|------------|
| Delonix regia (Hook.) Raf. | Fabaceae      | 72        | 32    | 31.2   | 3.6644     | 3.2947     |
| Dimocarpus longan Lour.     | Sapindaceae   | 126       | 33    | 32.3   | 2.8844     | 2.5649     |
| Diospyros discolor Willd.   | Ebenaceae     | 129       | 33    | 31.7   | 0.5116     | 0.4418     |
| Diospyros nigra (J.F.Gmel.) Perrier | Ebenaceae | 99      | 30    | 28.9   | 4.1445     | 4.5444     |
| Elaeocarpus hygrophiils Kurz | Elaeocarpaceae | 53      | 31    | 30.8   | 3.9787     | 3.5699     |
| Euphorbia kamponii Rauh and Petignat | Euphorbiaceae | 53    | 33    | 33.2   | 1.1899     | 1.3065     |
| Euphorbia laetia Aiton       | Euphorbiaceae | 81      | 34    | 33.5   | 4.8011     | 4.2920     |
| Fernandoa madagascariensis (Baker) A.H.Gentry | Bignoniaceae | 51     | 31    | 30.3   | 2.0645     | 1.8304     |
| Ficus benjamina L.           | Moraceae      | 151       | 30    | 29.8   | 3.2233     | 2.9034     |
| Ficus elastica Roxb. ex Hornem. | Moraceae   | 94        | 33    | 32.2   | 3.6151     | 3.2663     |
| Ficus lyrata Warb.           | Moraceae      | 104       | 32    | 31.4   | 6.1184     | 5.8793     |
| Guaiacum officinale L.       | Zygophyllaceae| 74      | 32    | 30.5   | 4.3365     | 3.8956     |
| Inga edulis Mart.            | Fabaceae      | 64        | 33    | 32.2   | 1.0848     | 0.9650     |
| Kopsia arborea Blume        | Apocynaceae   | 78        | 31    | 30.8   | 1.1323     | 0.9976     |
| Lagerstroemia indica L.      | Lythraceae    | 66        | 33    | 31.9   | 5.7112     | 5.1125     |
| Lagerstroemia speciosa (L.) | Lythraceae    | 78        | 33    | 32.1   | 6.3054     | 5.6616     |
| Leucaena leucocephala (Lam.) de Wit | Fabaceae  | 51        | 32    | 30.8   | 2.0202     | 2.2091     |
| Litchia elliptica Blume     | Lauraceae     | 62        | 32    | 31.3   | 2.1132     | 1.8935     |
| Magnolia × alba (D.C.) Figlar | Magnoliaceae | 145      | 32    | 31.8   | 1.6650     | 1.5148     |
| Mallotus barbatus Müll.Arg.  | Euphorbiaceae | 82       | 30    | 30.3   | 5.7765     | 5.1347     |
| Mangifera foetida Lour.      | Anacardiaceae | 57        | 33    | 33.4   | 7.4986     | 6.9429     |
| Mangifera indica L.          | Anacardiaceae | 61        | 33    | 33.5   | 4.0065     | 3.5847     |
| Melaleuca bracteata F. Muell. | Myrtaceae    | 96        | 31    | 30.2   | 1.0065     | 1.4466     |
| Morinda citrifolia L.        | Rubiaceae     | 61        | 30    | 30.7   | 1.3389     | 1.4678     |
| Moringa hildebrandtii Eng.   | Moringaceae   | 82        | 32    | 31.2   | 4.1132     | 3.6608     |
| Moringa oleifera Lam.        | Moringaceae   | 75        | 33    | 32.1   | 0.2211     | 0.1894     |
| Muntingia calabura L.        | Muntingiaceae | 66        | 32    | 31.1   | 1.5644     | 1.3886     |
| Nephelium lappaceum L.       | Sapindaceae   | 128       | 33    | 32.3   | 1.8886     | 1.6663     |
| Nerium oleander L.           | Apocynaceae   | 52        | 32    | 30.8   | 1.2234     | 1.1321     |
| Pachira aquatica Aub.        | Malvaceae     | 105       | 33    | 32.1   | 2.0044     | 1.7988     |
| Pachira insignis (Sw.) Savigny | Malvaceae    | 95        | 30    | 30.6   | 5.2123     | 5.8068     |
| Persea americana Mill.       | Lauraceae     | 126       | 33    | 32.5   | 1.5590     | 1.3232     |
| Phyllanthus acidus (L.) Skeels | Phyllanthaceae | 86   | 32    | 31.1   | 1.4391     | 1.5565     |
| Pithecellobium dulce (Roxb.) Benth. | Fabaceae | 96    | 32    | 31.8   | 1.6265     | 1.4517     |
| Plumeria rubra L.            | Apocynaceae   | 73        | 33    | 31.6   | 5.3795     | 5.9764     |
| Podocarpus neriifolius D.Don | Podocarpaceae | 85       | 30    | 29.8   | 4.3035     | 4.7965     |
| Polyalthia longifolia (Sonn.) Thwaites | Annonaceae | 93      | 33    | 32.1   | 3.1138     | 2.7105     |
| Pouteria campechiana (Kunth.) Baehni | Sapotaceae | 138    | 32    | 30.7   | 1.1133     | 2.0197     |
| Pseudobombax septenatum (Jacq.) Dugand | Malvaceae | 66      | 31    | 30.7   | 0.9922     | 0.8836     |
| Psidium guajava L.           | Myrtaceae     | 52        | 30    | 30.8   | 4.9597     | 5.5416     |
| Robinia hispida L.           | Fabaceae      | 66        | 33    | 31.8   | 2.4465     | 2.2247     |
| Sandoricum koetjape (Burn.f.) Merr. | Meliaceae | 141  | 33    | 32.1   | 1.9322     | 1.7042     |
| Saraca asoca (Roxb.) Willd.   | Fabaceae      | 72        | 31    | 30.3   | 4.1645     | 4.5679     |
| Saraca declinata Miq.        | Fabaceae      | 75        | 32    | 30.1   | 3.0111     | 3.3452     |
| Saraca thapingensis Prain    | Fabaceae      | 89        | 31    | 30.7   | 1.0946     | 1.1992     |
| Schizolobium parahyba (VII.) S.F.Blake | Fabaceae | 91    | 32    | 31.1   | 0.9955     | 0.8836     |
| Senegalia polyacantha (Willd.) Siegler and Ebinger | Fabaceae    | 81       | 33    | 31.8   | 3.7989     | 4.2265     |
| Sterculia foetida L.         | Malvaceae     | 141       | 33    | 32.4   | 3.4844     | 3.8877     |
| Syzygium cumini (L.) Skeels   | Myrtaceae     | 151       | 32    | 30.2   | 4.6075     | 3.9764     |
| Syzygium forte (F.Muell.) B.Hyland | Myrtaceae | 113  | 31    | 31.5   | 1.2134     | 1.3255     |
| Syzygium malaccense (L.) Merr. and L.M.Perry | Myrtaceae | 91    | 33    | 31.8   | 2.2233     | 2.4616     |
### Table A2. Cont.

| Species                  | Family       | Circ (cm) | Air T | Stem T | Sample 1 | Sample 2 |
|--------------------------|--------------|-----------|-------|--------|----------|----------|
| Tamarindus indica L.     | Fabaceae     | 119       | 33    | 32.2   | 6.6644   | 7.5740   |
| Tecoma stans Griseb.     | Bignoniaceae | 61        | 33    | 31.9   | 2.1645   | 2.3984   |
| Tectona grandis L.f.     | Lamiaceae    | 65        | 33    | 32.2   | 0.6566   | 0.6943   |
| Terminalia catappa L.    | Combretaceae | 53        | 30    | 30.5   | 2.4844   | 2.7771   |
| Terminalia ivorensis A.Chev. |          | 69        | 33    | 31.9   | 3.5467   | 3.9865   |
| Triplaris americana L.    | Polygonaceae | 97        | 32    | 31.1   | 2.5546   | 2.8403   |
| Xanthostemon chrysanthus (F.Muell.) Benth. | Xanthorrhoeaceae | 96        | 33    | 32.2   | 3.6134   | 4.0395   |

### Table A3. List of non-palm arborescent monocot species included in the carbon dioxide efflux study. Circ = circumference, Air T = air temperature, and Stem T = surface temperature of stems.

| Species                  | Family       | Circ (cm) | Air T | Stem T | Sample 1 | Sample 2 |
|--------------------------|--------------|-----------|-------|--------|----------|----------|
| Beaucarnea recurvata Lem. | Asparagaceae | 84        | 31    | 30.2   | 3.1848   | 2.8466   |
| Dasylirion wheeleri S.Watson ex Rothr. | Asparagaceae | 99        | 33    | 32.6   | 4.4489   | 4.0032   |
| Dracaena cochinchinensis (Lour.) S.C.Chen | Asparagaceae | 117       | 32    | 31.5   | 2.9441   | 2.6509   |
| Dracaena dereminis Engl. | Asparagaceae | 58        | 33    | 32.5   | 1.2234   | 1.0730   |
| Dracaena floribunda Baker | Asparagaceae | 101       | 33    | 32.2   | 2.0498   | 1.8304   |
| Dracaena fragrans (L.) Ker Gaw. | Asparagaceae | 66        | 33    | 32.1   | 3.4899   | 3.0927   |
| Ensete ventricosum (Welw.) Cheesman | Musaceae      | 175       | 33    | 31.8   | 4.7003   | 4.2099   |
| Musa x paradisiaca L.    | Musaceae     | 75        | 30.5  | 3.2614 | 2.4668   | 2.6798   |
| Pandanus dubius Spreng.  | Pandanaceae  | 73        | 32    | 31.7   | 3.5564   | 3.9888   |
| Pandanus rubiensis Rendle. | Pandanaceae  | 64        | 33    | 32.1   | 3.9166   | 3.4714   |
| Pandanus tectorius Parkinson ex Du Roi | Pandanaceae | 58        | 32    | 31.8   | 0.7568   | 0.8205   |
| Pandanus vandermeeschii Balff. | Pandanaceae | 68        | 31    | 30.3   | 3.8465   | 4.2920   |
| Pandanus veitchii Mast.  | Pandanaceae  | 72        | 33    | 32.2   | 2.1779   | 2.3984   |
| Ravenala madagascariensis Sonn. | Strelitziaceae | 85        | 31    | 30.6   | 1.0044   | 0.9468   |
| Strelitzia alba (L.f.) Skeels | Strelitziaceae | 51        | 32    | 31.1   | 3.5668   | 4.0547   |
| Xanthorrhoea glauca D.J.Bedford | Xanthorrhoeaceae | 78        | 31    | 31.5   | 1.4465   | 1.5779   |

### Table A4. List of the Arecaceae species included in the carbon dioxide efflux study. Circ = circumference, Air T = air temperature, and Stem T = surface temperature of stems.

| Species                  | Circ (cm) | Air T | Stem T | Sample 1 | Sample 2 |
|--------------------------|-----------|-------|--------|----------|----------|
| Adonia merrillii (Becc.) Becc. | 66        | 33    | 31.9   | 1.4868   | 1.3255   |
| Alphines minima (Gaertn.) Burret | 53        | 33    | 31.8   | 3.792    | 3.6797   |
| Allagoptera caudescens (Mart.) Kuntze | 52        | 32    | 30.8   | 1.6623   | 1.8051   |
| Archontophoenix myloensis Dowe | 87        | 31    | 32.8   | 2.4465   | 2.1460   |
| Archontophoenix purpurea Hodel and Dowe | 51        | 32    | 31.2   | 4.1657   | 3.6645   |
| Areca catechu L.          | 59        | 32    | 31.8   | 1.8165   | 2.0134   |
| Areca macrocarpa Becc.    | 61        | 33    | 32.1   | 3.7979   | 4.3046   |
| Areca parrisi Becc.       | 59        | 33    | 33.9   | 3.2136   | 3.5649   |
| Astrocaryum mexicanum Leibm. Ex Mart. | 51        | 32    | 31.1   | 2.5644   | 2.2722   |
| Beccariophoenix alfredii Rakotarain., Ranariv. and J.Dransf. | 182       | 33    | 32.9   | 1.1165   | 0.9864   |
| Beccariophoenix madagascariensis Jum. and H.Perrier | 103       | 32    | 31.2   | 3.6645   | 4.0031   |
| Bentinckia nicobarensis (Kurz.) Becc. | 65        | 32    | 31.8   | 3.1619   | 3.4466   |
| Borassodendron machadonis Becc. | 127       | 33    | 31.2   | 2.8645   | 3.1165   |
| Brassiophoenix schumanni (Becc.) Essig | 52        | 33    | 32.1   | 1.7115   | 1.5274   |
| Burretiochenta dumasis Pintaud and Hodel | 51        | 32    | 31.1   | 2.7654   | 3.0031   |
| Burretiokentia grandiflora Pintaud and Hodel | 52        | 32    | 31.7   | 4.2958   | 4.7799   |
| Burretiokentia vieillardii (Brongn. and Gris) Pic.Serm. | 51        | 33    | 31.9   | 0.8286   | 0.8898   |
| Species | Circ (cm) | Air T | Stem T | Sample 1 | Sample 2 |
|---------|----------|-------|--------|----------|----------|
| Calyptrocalyx spicatus (Lam.) Blume | 52 | 34 | 32.9 | 1.2989 | 1.1361 |
| Calyptronoma rivalis (O.F.Cook) L.H.Bailey | 66 | 33 | 31.7 | 2.6798 | 2.9765 |
| Carpentaria acuminata (H.Wendl. and Drude) Becc. | 52 | 33 | 32.2 | 2.7272 | 1.7042 |
| Carpoxylon macrospermum H.Wendl. and Drude | 67 | 32 | 30.9 | 0.9346 | 0.9979 |
| Caryota ophiopellos Dowre | 81 | 32 | 31.1 | 3.9966 | 4.9643 |
| Chameleyronia macrocarpa (Brongn.) Vieill. Ex Becc. | 51 | 33 | 32.1 | 1.8879 | 1.6410 |
| Chelyocarpus chuco (Mart.) H.E.Moore | 68 | 32 | 31.6 | 0.9346 | 0.9979 |
| Chelyocarpus ulei Dammer | 51 | 31 | 31.8 | 4.7474 | 5.2646 |
| Clinostigma ponapense (Becc.) H.E.Moore and Fosberg | 105 | 32 | 31.4 | 2.2722 | 1.7042 |
| Clinostigma samoense H.Wendl. | 68 | 33 | 31.8 | 2.2722 | 1.7042 |
| Cocos nucifera L. | 105 | 32 | 31.4 | 4.7474 | 5.2646 |
| Colpothrinax wrightii Griseb. and H.Wendl. ex Voss | 101 | 33 | 32.2 | 1.8445 | 1.6410 |
| Copernicia baileyana Lam. | 162 | 32 | 31.5 | 0.9631 | 0.9987 |
| Copernicia hospita Mart. | 61 | 31 | 30.3 | 3.0844 | 3.4125 |
| Copernicia prunifera (Mill.) H.E.Moore | 64 | 33 | 32.1 | 4.9497 | 5.4895 |
| Copernicia sp. Mart. ex Endl. | 68 | 32 | 31.6 | 4.9497 | 5.4895 |
| Corypha utan Lam. | 101 | 33 | 32.1 | 1.8445 | 1.6410 |
| Cryosophila warscewiczii (H.Wendl.) Bartlett | 61 | 33 | 31.9 | 4.0054 | 3.6103 |
| Cryosophila williamsii P.H.Allen | 52 | 32 | 31.1 | 5.4986 | 5.0896 |
| Cyphophoenix elegans (Brongn. and Gris) H.Wendl. ex Salomon | 51 | 33 | 32.1 | 2.7298 | 2.3755 |
| Cyphophoenix nucle H.E.Moore | 52 | 32 | 31.6 | 3.1959 | 3.0296 |
| Cyrtostachys elegans Burret | 58 | 32 | 31.1 | 4.1121 | 3.6570 |
| Cyrtostachys lorae Becc. | 52 | 33 | 31.2 | 3.1645 | 2.8165 |
| Dictyosperma album (Bory) Scheff. | 58 | 32 | 31.3 | 3.1959 | 3.0296 |
| Dypsis arenaranum (Jum.) Beentje and J.Dransf. | 63 | 34 | 33.1 | 4.1121 | 3.6570 |
| Dypsis caudatae (H.E.Moore) Beentje and J.Dransf. | 52 | 33 | 32.7 | 3.1165 | 2.9765 |
| Dypsis carlsmithii J.Dransf. and Marcus | 77 | 33 | 32.9 | 4.6002 | 4.1165 |
| Dypsis decaryi (Jum.) Beentje and J.Dransf. | 81 | 32 | 31.2 | 3.4497 | 3.1333 |
| Dypsis hovomantsina Beentje | 62 | 33 | 33.7 | 1.3868 | 3.1349 |
| Dypsis ifanadianae Beentje | 58 | 33 | 33.1 | 4.1546 | 3.8845 |
| Dypsis lastelliana (Baill.) Beentje and J.Dransf. | 77 | 33 | 33.2 | 6.1132 | 5.6068 |
| Dypsis madagascariensis (Becc.) Beentje and J.Dransf. | 55 | 34 | 33.5 | 5.7746 | 5.1270 |
| Dypsis mananjarensis (Jum. and H.Perrier) Beentje and J.Dransf. | 65 | 34 | 31.9 | 3.8465 | 3.4545 |
| Dypsis montana (Jum.) Beentje and J.Dransf. | 65 | 33 | 32.2 | 4.0064 | 3.6699 |
| Dypsis pembana (H.E.Moore) Beentje and J.Dransf. | 68 | 29 | 28.1 | 4.9599 | 4.2236 |
| Dypsis plumosa Hodel, J.Marcus and J.Dransf. | 62 | 32 | 31.5 | 1.9976 | 2.8965 |
| Dypsis robusta Hodel, Marcus and J.Dransf. | 69 | 34 | 33.9 | 1.8465 | 1.6410 |
| Dypsis santeuciei Beentje | 55 | 34 | 33.1 | 1.9292 | 1.7042 |
| Elaeis guineensis Jacq. | 118 | 33 | 32.2 | 1.1645 | 1.0235 |
| Euterpe precatoria Mart. | 51 | 32 | 31.4 | 2.4265 | 2.1775 |
| Heterospathes elegans Becc. | 64 | 33 | 32.1 | 2.3164 | 2.1050 |
| Heterospathes intermedia (Becc.) Fernando | 51 | 32 | 31.2 | 4.3465 | 3.9133 |
| Heterospathes sibogianensis Becc. | 74 | 34 | 31.9 | 2.0065 | 1.8304 |
| Hydrastele moluccana (Becc.) W.J.Baker and Loo | 84 | 34 | 33.1 | 3.8844 | 3.4466 |
| Hystophorbe lagenaicus (L.H.Bailey) H.E.Moore | 151 | 31 | 30.4 | 2.8897 | 2.5878 |
| Itaya anticorum H.E.Moore | 55 | 32 | 30.9 | 2.4264 | 2.1460 |
| Krentiospis piersoniorum Pintaud and Hodel | 55 | 33 | 32.1 | 1.4465 | 1.3255 |
| Krentiospis pyriforna Pintaud and Hodel | 65 | 32 | 31.2 | 3.6611 | 3.2821 |
| Laccospadix australasicus H.Wendl. and Drude | 51 | 33 | 32.7 | 1.7996 | 1.5969 |
| Licuala bayana Saw | 51 | 32 | 30.8 | 2.1132 | 1.8935 |
| Licuala petata Roxb. | 58 | 32 | 31.3 | 1.0054 | 0.8836 |
| Licuala sallhiana Saw | 69 | 30 | 29.1 | 1.6632 | 1.5148 |
| Livistona lanuginosa Rodd | 97 | 33 | 32.1 | 2.8277 | 2.5247 |
Table A4. Cont.

| Species                          | Circ (cm) | Air T | Stem T | Sample 1  | Sample 2  |
|---------------------------------|-----------|-------|--------|-----------|-----------|
| Livistona mariae F.Muell.       | 88        | 33    | 32.3   | 1.1312    | 0.9957    |
| Livistona muelleri F.M.Bailey    | 74        | 32    | 31.5   | 1.8486    | 1.6410    |
| Livistona victoriae Rodd        | 79        | 31    | 30.9   | 1.6645    | 1.5148    |
| Lodoicea maldivica (J.F.Gmel.) Pers. | 98    | 34    | 34.6   | 1.1132    | 0.9720    |
| Medenia argun (Mart.) Wurttenb. ex H.Wendl. | 117  | 32    | 30.3   | 2.7918    | 2.5878    |
| Neonicholsonia watsonii Drammer | 52        | 32    | 30.8   | 1.7765    | 1.5148    |
| Neoveitchia brunnnea Dowre      | 55        | 33    | 31.8   | 2.0021    | 1.8051    |
| Neoveitchia storckii (H.Wendl.) Becc. | 73   | 32    | 31.2   | 1.2345    | 1.1109    |
| Nephrosperma van-houtteanum (H.Wendl. ex Ván Houtte) | 52   | 33    | 32.3   | 2.7711    | 2.4657    |
| Neocarpus mapora H.Karst        | 51        | 32    | 31.1   | 5.5056    | 4.9231    |
| Oenocarpus mapora H.Karst       | 68        | 29    | 28.6   | 1.6465    | 1.4391    |
| Orania mollucana Becc.          | 67        | 32    | 31.3   | 1.4215    | 1.2231    |
| Phoenix sylvestris (L.) Roxb.   | 109       | 31    | 32.3   | 3.7164    | 4.1312    |
| Pinanga batanensis Becc.        | 68        | 34    | 32.9   | 3.6134    | 4.0066    |
| Pinanga insignis Becc.          | 48        | 33    | 31.9   | 2.0311    | 1.8304    |
| Pinanga javana Blume            | 51        | 34    | 32.8   | 2.1798    | 1.9566    |
| Pinanga urosperma Becc.         | 61        | 33    | 31.9   | 0.9554    | 0.8205    |
| Ponapea hosinai Kaneh.          | 62        | 33    | 31.8   | 5.4165    | 6.0023    |
| Pritchardia thorstonii F.Muell. and Drude | 52  | 32    | 30.8   | 4.0154    | 4.4651    |
| Ptychosperma elegans (R.Br.) Blume | 53    | 32    | 31.2   | 6.3897    | 7.1322    |
| Ravenea madagascariensis Becc.  | 52        | 34    | 33.2   | 0.9489    | 1.0211    |
| Rhopaloblaste augusta (Kurz.) H.E.Mllre | 58   | 33    | 32.2   | 1.6355    | 1.4517    |
| Sabal mauritiiformis (H.Karst.) Griseb. and H.Wendl. | 71   | 32    | 31.4   | 3.1134    | 3.2265    |
| Sabal palmetto (Loder) Walter ex Schult. and Schult.f. | 95   | 31    | 31.3   | 1.3444    | 1.2231    |
| Saribus rotundifolius (Lam.) Blume | 105  | 30    | 30.1   | 1.1314    | 1.0099    |
| Satakentia liukiuensis (Hatus.) H.E.Moore | 68   | 32    | 31.5   | 7.5109    | 6.3365    |
| Schippia concolor Burret         | 51        | 33    | 32.4   | 0.7544    | 0.7547    |
| Syagrus botryophora (Mart.) Mat. | 76        | 32    | 32.6   | 1.7655    | 1.5779    |
| Syagrus romanzoffiana (Cham.) Glassman | 63    | 33    | 32.1   | 1.6215    | 1.1165    |
| Syagrus sancona (Kunth.) H.Karst. | 78        | 32    | 31.8   | 1.6311    | 1.4517    |
| Syagrus schizophylla (Mart.) Glassman | 56    | 32    | 31.1   | 1.5644    | 1.3886    |
| Veitchia joannis H.Wendl.        | 59        | 33    | 32.2   | 1.3433    | 1.1992    |
| Washingtonia robusta H.Wendl.   | 154       | 32    | 31.3   | 4.6899    | 4.2288    |
| Wodyetia bifurcata A.K.Irvine    | 99        | 30    | 31.6   | 4.4454    | 3.9764    |

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