

1 Title page

2 Measuring Orangutan nest structure using Unmanned Aerial Vehicle (UAV) 3 and ImageJ

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6 Salniza Akmar Kamaruszaman^{1¶}, Nik Fadzly^{1¶,*}, Aini Hasanah Abd Mutualib^{1¶}, Aidy M.
7 Muslim^{3&}, Sri Suci Utami Atmoko^{4&}, Mashhor Mansor^{1&}, Asyaf Mansor^{1,2&}, Nadine Rupert^{1&},
8 Rahmad Zakaria^{1&}, Zarul Hazrin Hashim^{1,2&}, Amir Shah Ruddin Md Sah^{1&}, Fadhirul Fitri
9 Jamsari^{5&}, and Nur Munira Azman^{1&}

10 ¹School of Biological Sciences, Universiti Sains Malaysia, 11800 Minden, Penang, MALAYSIA,

¹¹ ²Centre for Marine and Coastal Studies (CEMACS), Universiti Sains Malaysia, 11800 Minden, Penang, MALAYSIA.

12 ³Institute of Oceanography and Environment (INOS), Universiti Malaysia Terengganu, 21030 Kuala Terengganu,
13 MALAYSIA.

14 ⁴Fakultas Biologi, Universitas Nasional Jakarta, 12520, INDONESIA.

15 ⁵OFO Tech Sdn Bhd, Kuala Lumpur, 21-2, Jalan Wangsa Delima 10, Wangsa Maju, 53300 Wangsa Maju, Federal
16 Territory of Kuala Lumpur ,MALAYSIA.

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18 * Corresponding author

19 Email: nroselnik@outlook.com

²⁰ ¶ These authors contributed equally to this work

²¹ & These authors also contributed equally to this work

22

22

24 **Abstract**

25

26 The nest is one of the crucial elements in orangutan daily activities. Previously, most of the nest
27 structure studies were done manually by estimating measurement directly from visual observation.
28 However, using the latest unmanned aerial vehicle (UAV) technology, we can reduce the
29 workforce, time and energy while simultaneously ensuring the safety of the researcher conducting
30 nest structure analysis. We recorded 49 pictures of orangutan nests at Sepilok Orangutan
31 Rehabilitation Centre (SORC) using UAV (DJI Phantom 3 Quadcopter). The nest structure
32 (length, depth, and width) was digitally measured by using ImageJ. Most of the nests were built at
33 a strong, stable, and comfortable position at the top of the tree. Most orangutans chose
34 *Eusideroxylon zwageri* to build nest compared to other tree species because of the strong and
35 durable wood characteristic which would create a sturdy, strong and comfortable nest. We propose
36 the use of drone with digital image analysis could provide a more accurate, less time consuming
37 and safe method for studying orangutan nest structure.

38 Keywords: Bornean orangutan, nest structure, UAV, Drone, image analysis, nest measurement

39

40 **Introduction**

41

42 Arboreal great apes especially orangutans need to master the nest building skill together with other
43 skills such as climbing, foraging and being able to identify their natural predators [1-4]. The nest
44 building is a skill inherited through observation on the mother's or other adults' nesting practices
45 [2, 3, 5, 6]. Nests served as a "bed" for resting and sleeping, hiding from danger or predator, as
46 well as for a better thermoregulation [4, 5, 7].

47 Previously, most of the orangutans' nest studies were based on ecological aspects such as density
48 estimation, distribution and population of orangutans in a habitat, nesting preferences and
49 mechanisms and material to build a nest and its decaying rates [7-12]. Nest measurement and
50 materials used are evaluating characteristics of the nest building skill of an individual and the
51 quality of the nest built [6, 13]. However, researchers must conduct rigorous, time and energy
52 consuming techniques such as tree climbing to study the orangutan's nest structures. Even though
53 direct nests measurement by climbing techniques might provide a more accurate reading, a new
54 approach using Unmanned Aerial Vehicle (UAV) has been developed for nest survey and
55 observation during this decade [7, 11, 13-15].

56 The application of UAV or drones technology was once limited to the military. However,
57 the usage of drones has spread widely and no longer exclusive to the military. Drones are used in
58 civilian use such as monitoring, transportation for goods delivery as well as site inspections [16,
59 17]. These drones have the capability to capture images through rapid data acquisition, which is
60 an advantage for scientific research especially for animals conservations [8, 11, 16-19]. This study
61 aims to determine the variation of nest structure quantitatively via image analysis through
62 utilization of drones.

63

64 **Materials and Method**

65

66 We obtained the permission to conduct the study from Sabah Biodiversity Centre (SaBC) with
67 the support of Sabah Wildlife Department (SWD) and Sabah Forestry Department (SFD). The
68 study was done at 5°51'51.82"N, 107°56'55.72"E; Sepilok Orangutan Rehabilitation Center
69 (SORC), Sandakan Sabah within 6 months from January 2016 to April 2017. SORC is located

70 within Kabili-Sepilok Forest Reserved with an area of 4294 hectares with more than 200
71 Orangutans (Fig 1).

72 **Fig 1** The area of study; Sepilok Orangutan Rehabilitation Centre (Map by Aini Hasanah Abd
73 Mutualib).

74

75 We tested a new experimental design by adapting to the nest description outlined by Samson and
76 Hunt (6). We utilized the use of Unmanned Aerial Vehicle (UAV) to capture the orangutan nests
77 images [11, 20]. We used the DJI Phantom 3 Professional fitted with a 12-megapixel camera (f/2.8
78 lens 94° field view). Image capture process was done without the presence of the orangutans during
79 daytime for safety purposes (for the researchers and the orangutan). Our skilled licensed drone
80 pilots managed to fly the drone as close as within 1 to 3 meters of the nest. The side and top view
81 of the nest were recorded at a screen resolution of 72 dpi (dot per inch) which equals to 300 dpi in
82 print resolution. The digital scale measurement of the nests' structure was estimated by using leaf
83 samples of the tree where the nests were recorded. We used a slingshot to obtain the leaf samples
84 from the nearest branch of the nest. The leaf samples were measured by using a ruler to obtain the
85 length. Ten samples of the leaves were measured and we used the average value. In the ImageJ
86 software, we used the measured length as the digital scale for the overall image analysis. ImageJ
87 software was used to measure the nest length, width, and depth. The digital measurement of the
88 nest was illustrated in Fig 2.

89 **Fig 2** The mechanism of nest measurement using the ImageJ analysis was modified from van
90 Casteren *et al.*,[7]. **1.** Leaf sample (red boxes) was measured and set as digital scale (cm).
91 **2.** The length of the nest was measured, the depth of the nest was taken from the centre of the
92 nest. **3.** The nest width was measured perpendicular to the length.

93

94 Other ecological parameters (nest class and position, canopy cover, tree height, nest height,
95 and tree species) were also recorded through direct observation. Nest class and position were
96 classified based on Utami Atmoko and Arif Rifqi (4) and Prasetyo, Utami (1). The nest canopy
97 cover was classified directly through observation in the field. The nest was categorized as closed
98 nest if there was the presence of tree canopy, vegetation, or any obstacle above the nest. A nest
99 was considered as an open nest with the absence of any obstacles that prevent direct sunlight to
100 the nest. The tree and nest height was either measured by using a clinometer (Suunto PM-5, PM-
101 5/1520) or estimated through observation. The tree species were identified by the available tree id
102 tags and later reconfirmed by the SFD's staff. The data were analyzed by using statistical software
103 JMP 10. The variables that were not normally distributed were transformed using log to meet the
104 condition of normal distribution for parametric analyses. If normality could not be achieved, we
105 proceeded to use non-parametric analyses.

106

107 **Results**

108

109 We recorded a total of 49 nests. Fig 3a shows most of the nest were built at tree branch or position
110 2 with 25 nests count followed by position 3 (16 nests) and position 1 (8 nests). Fig 3b shows that
111 27 of the nests recorded were from class 3 followed by class 1 (11 nests), class 2 (10 nests) and
112 class 4 (1 nest). In this study, we do not encounter any nest with position 4.

113 **Fig 3** The bar graph of number of nests built by orangutans based on **a)** nest position and **b)** nest
114 class.

115 The average nest length, width and depth recorded were 87.323 ± 29.472 cm, 59.889 ± 18.313 cm
116 and 36.666 ± 16.009 cm, respectively. The average height of the tree, and the height of nest were
117 16.166 ± 7.686 m, and 12.176 ± 6.866 m, respectively. 65.63% of the nests were open nest and
118 34.63% of the nests were closed nest (Fig 4).

119 **Fig 4** The pie chart shows the percentage nests built according to nest cover. Inset picture 1 and 2
120 show an open nest, inset picture 3 and 4 show a closed nest, from the top and side view.

121
122 There was no significant difference for nest position according to nest length (Kruskall-Wallis, χ^2
123 $= 2.138$, $df = 2$, $P = 0.343$) and depth (Kruskall-Wallis, $\chi^2 = 2.108$, $df = 2$, $P = 0.349$). There was
124 also no significant difference for the nest width based on the nest position (ANOVA, $F (2,77) =$
125 1.839 , $P = 0.166$). There was no significant difference for the nest class based on the nest length
126 (Kruskall-Wallis, $\chi^2 = 4.304$, $df = 3$, $P = 0.231$).

127 There is a significant difference of nest depth based on the nest class (Kruskall-Wallis, $\chi^2 = 13.408$,
128 $df = 2$, $P = 0.001$) (Fig 5). The depth of nest decreased with the nest class. Class 3 nest recorded
129 the thinnest depth (34.560 ± 3.613 cm) compared to nest from class 1 (52.200 ± 2.032 cm) and class
130 2 (57.000 ± 2.430 cm). There was no significant difference for nest class according to the nest
131 width ($F (3,77) = 2.187$, $P = 0.097$). Tree height and nest height showed a strong positive and
132 significant correlation ($r_s = 0.7867$, $p = 0.0001$) (Fig 6).

133 **Fig 5** : The nest depth based on the nest class distribution.

134 **Fig 6:** The correlation between a) height (log) of tree and height of nest

135
136 From the 49 nests recorded, 46.94% (23 nests) were found on *Eusideroxylon zwageri*, 20.41% (10
137 nests) on *Nephelium rambutan-ake*, 8.16% (4 nests) on *Litsea* sp. and *Syzygium rejangense*, 4.08%

138 (2 nests) *Pometia pinnata* and *Pentace laxiflora* and 2.04% (1 nest) on *Koordersiodendron*
139 *pinnatum*, *Knema latifolia*, *Shorea johorensis*, and *Nephelium lappaceum*. (Fig 7)

140 **Fig 7:** The frequency of tree species used for nesting by orangutan.

141 **Discussion**

142

143 The aim of this study was to determine the variation of nest structure quantitatively using advance
144 drone and image analysis software. We aim to promote our method as a new approach in nest
145 measurement. Rayadin and Saitoh (13) recorded the nest average of length measurement of 114.5
146 cm. The average nest length for small juvenile to adult flange male was 64.1 cm to 139.3 cm. In
147 this study, the average length of nest was 87.32 cm, which is within the range of the previous
148 studies. However, we could not identify the individual that built the nest since we did not follow
149 any orangutans. We were only allowed to use the drone when the orangutans had left the nest, for
150 safety purposes. However, through observation we noted that juveniles and adults of both sex
151 frequented the nests. We did not observe any adult flange male near our observed nests. Flanged
152 male individual tend to avoid crowd areas, therefore their nest might be secluded.

153 Most of the nests at our study site were built on top of the tree with open nest cover. Ancrenaz,
154 Calaque (12) reports that most of the orangutans build their nest on top of a single tree. Orangutans
155 tend to choose higher trees to nest on regardless the age groups and sex [13, 21]. The trees in our
156 study sites averages at 16.60 m where the top position might offer a stable and balanced position.
157 Orangutans might have avoided small trees as they preferred strong and sturdy branches to support
158 their concave shape nests. This is similar to chimpanzee nest selection preference, in which they
159 preferred sturdy, strong and comfortable spot to build nest [1, 5-7].

160 Our results showed no significant differences between the nest sizes cumulatively. However,
161 several studies have shown that nests size increases with the age group. This is related to the body
162 size where adult flange male with large body size built larger nest compare to the juvenile with a
163 small body [7, 13]. In our study site, since we did not detect any adult flanged male nesting and
164 most of the nests that we sampled were frequented by orangutans within a similar age group and
165 body sizes. There is a possibility that a larger sample size could provide more information in the
166 future.

167 The significant correlation between tree height and nest height supports the hypothesis which
168 orangutans were more likely to build the nest at the very top of the tree. The decaying process
169 might also have contributed to the significant difference between nest class and nest depth [10].
170 Class 3 is considered as the second last stage of nest decay. Orangutans usually repairs certain nest
171 spots that are their favorite, which is why nest class 1 and 2 is frequently used. However, the decay
172 rate or factors affecting the decay process and decay process related to nest class quality were not
173 recorded in this study. There is also the possibility that the depth of the nest was influenced by the
174 orangutan body weight. Orangutan would position themselves in the middle of the nest and their
175 body weight would depress the whole nest. Unfortunately, since we did not specifically track
176 individual orangutans to a specific nest, we could not confirm this effect. There was also no
177 assessment related to the animal physical measurement such as weight and body size as we were
178 not allowed to physically touch the orangutans.

179 Orangutan most likely avoided building nest on fruit trees as precautions steps from other
180 individuals especially flange males or other frugivorous animals. However, with limited
181 availability of fruit, there were cases where an individual would select the non-fruiting tree to build
182 their nest [5, 21, 22]. Orangutans do have individual preferences in where to rest and sleep [4, 5].

183 Orangutans shows intelligence in nest building by choosing the best materials from hard and
184 durable tree species such as *E. zwageri* tree (commonly known as a Belian tree). Compared to
185 other tree species, the Belian tree would provide the orangutans a sturdy and strong nest to support
186 their weight. This valuable timber is widely used by human to produce furniture, medicinal
187 purposes as well as in traditional rituals [23-26]. The frequent usage of this tree species also
188 indicates that orangutans chose their nesting site based on strong and sturdy tree more for their
189 comfort [27].

190 In natural settings, orangutans are solitary and have the tendency to avoid crowd and predators
191 including human [4, 28, 29]. In this study, we noticed that most of the orangutans have become
192 habituated with the human presence since most of the nests recorded were located near the feeding
193 platforms and boardwalk; a place where the visitors could access and observe the orangutan's
194 activities. We also suspected that this phenomenon was also due to food availability since the food
195 will be given to them every 10 a.m. and 3 p.m. regardless to the presence of visitors.

196 However, we must highlight the fact that the orangutans in Sepilok were in a rehabilitation
197 program which indirectly means that they were already familiar with human presence since they
198 have been exposed to human care. To release them into the wild, the juvenile orangutans were
199 released in the rehabilitation area within the 4,294-hectare forest. This was the next step in
200 preparing the orangutans to be released in the wild. The orangutan need to forage, build their own
201 nest, and subsequently making them less dependent on human care. Nest building skills is a very
202 crucial and important skill for orangutan to survive in the wild. Therefore, research on the nest
203 structure of orangutan is a very important. We propose that our method would be used as a standard
204 for future nest studies.

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206

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283



Legend

Landuse Sepilok



Name

- Forest
- Human Settlement
- Mixed plantations
- Oil Palm
- Road
- Water Body



Miles

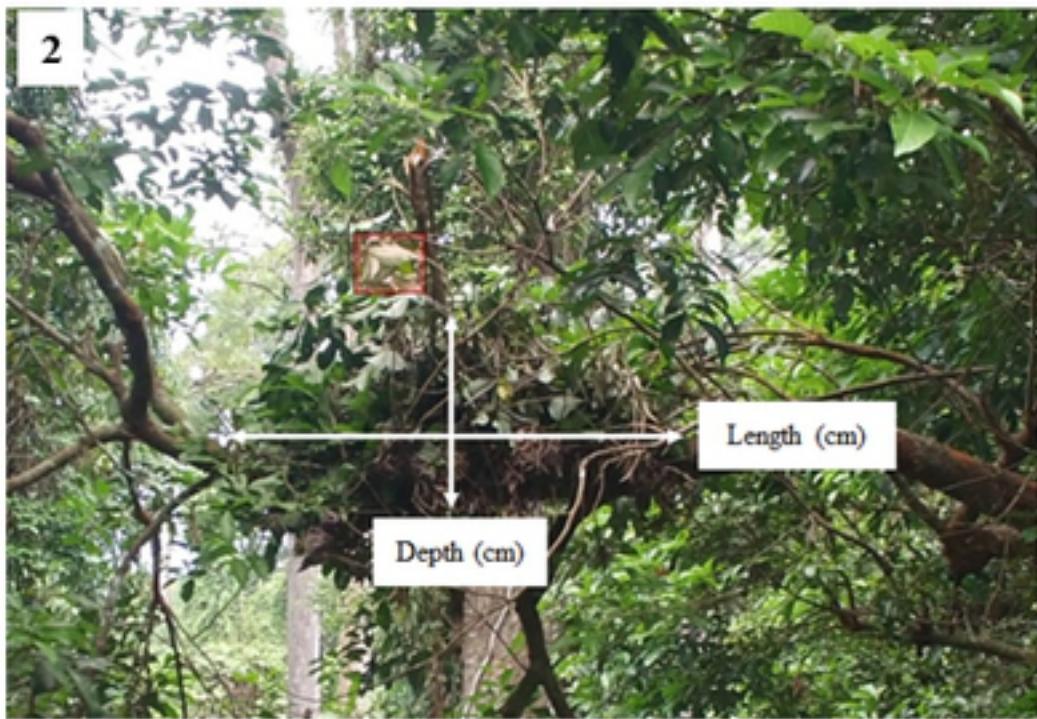
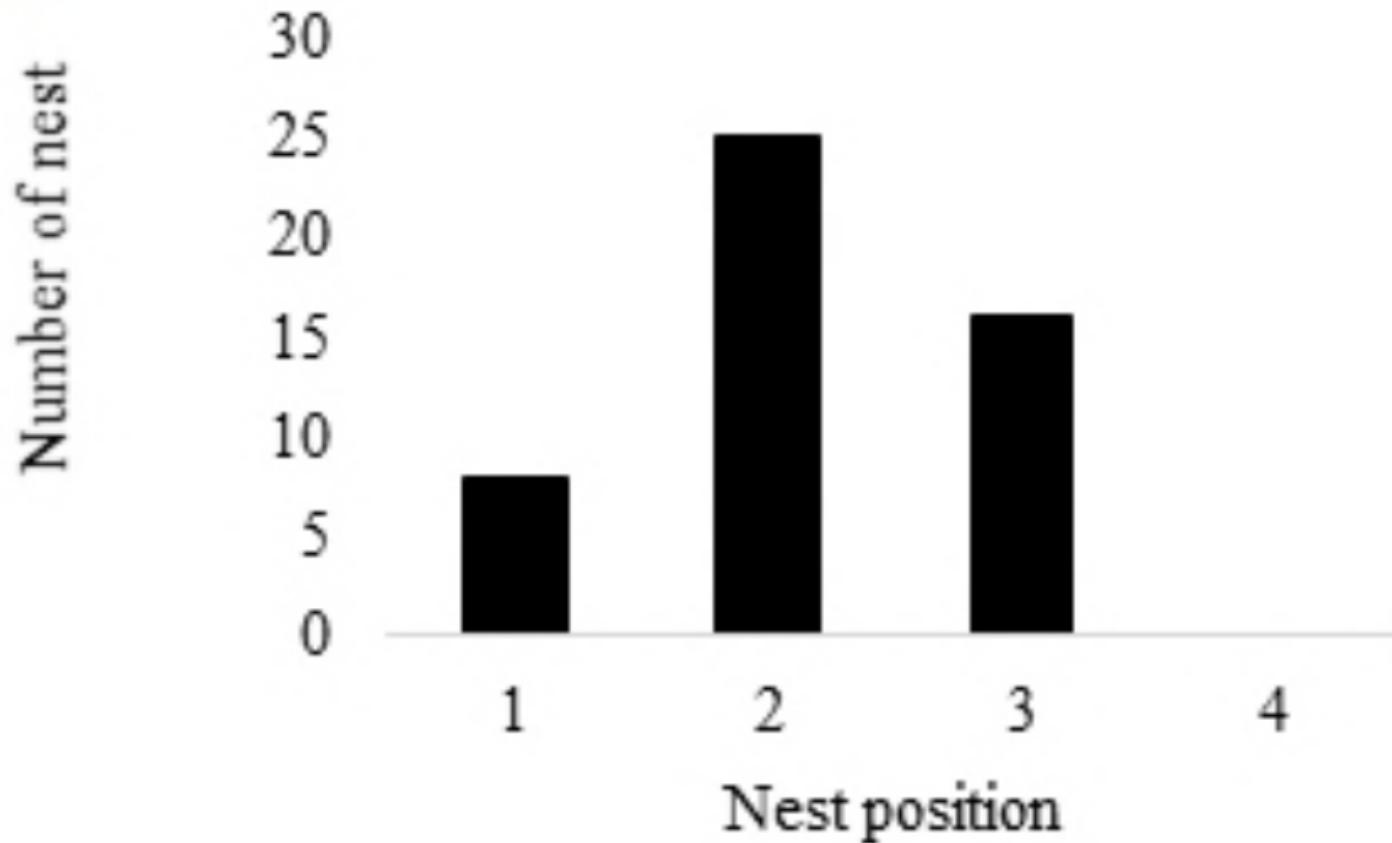
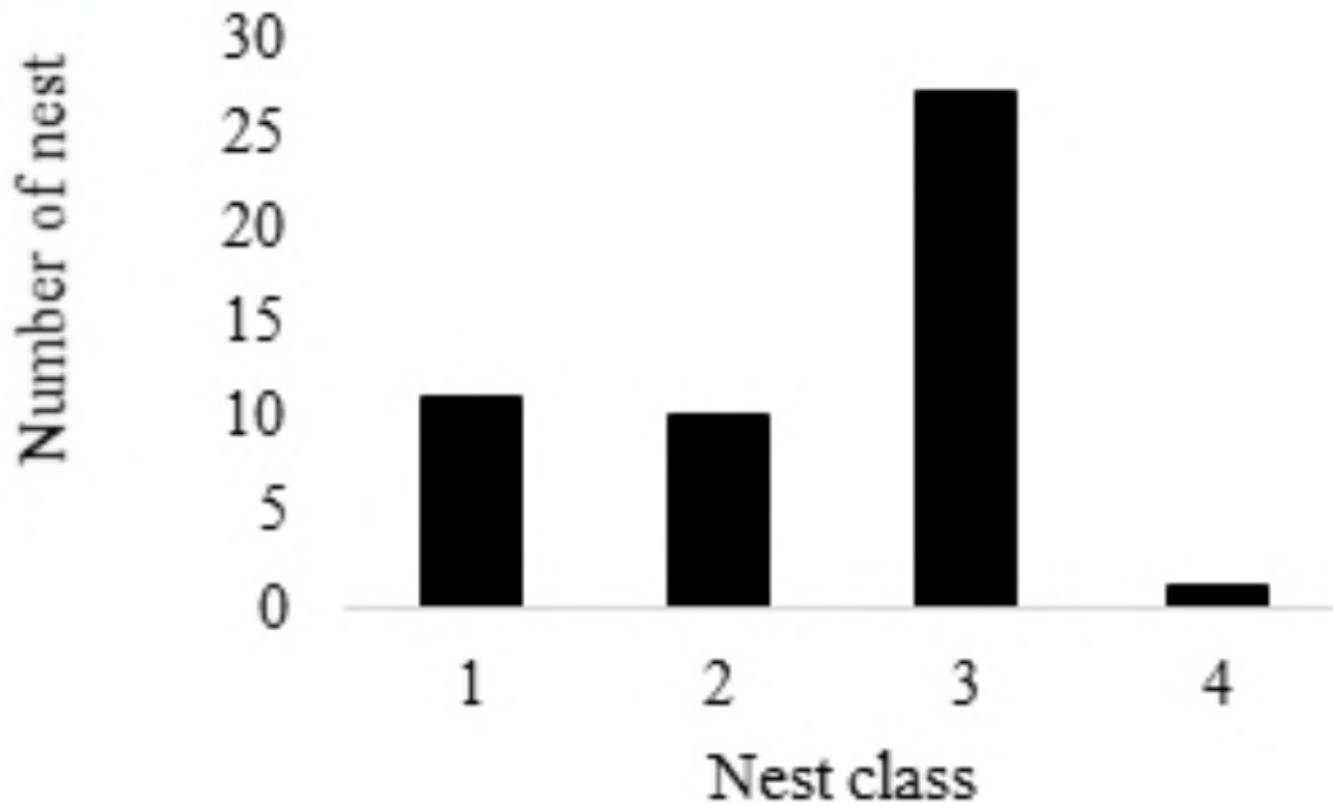


Fig 2 The mechanism of nest measurement using the ImageJ analysis was modified from van Casteren *et al.*, (2012). **1.** Leaf sample (red boxes) was measured and set as digital scale (cm). **2.** The length of nest was measure, the depth of the nest was taken from the centre of the nest. **3.** The nest width was measured perpendicular to the length arrow.

a)



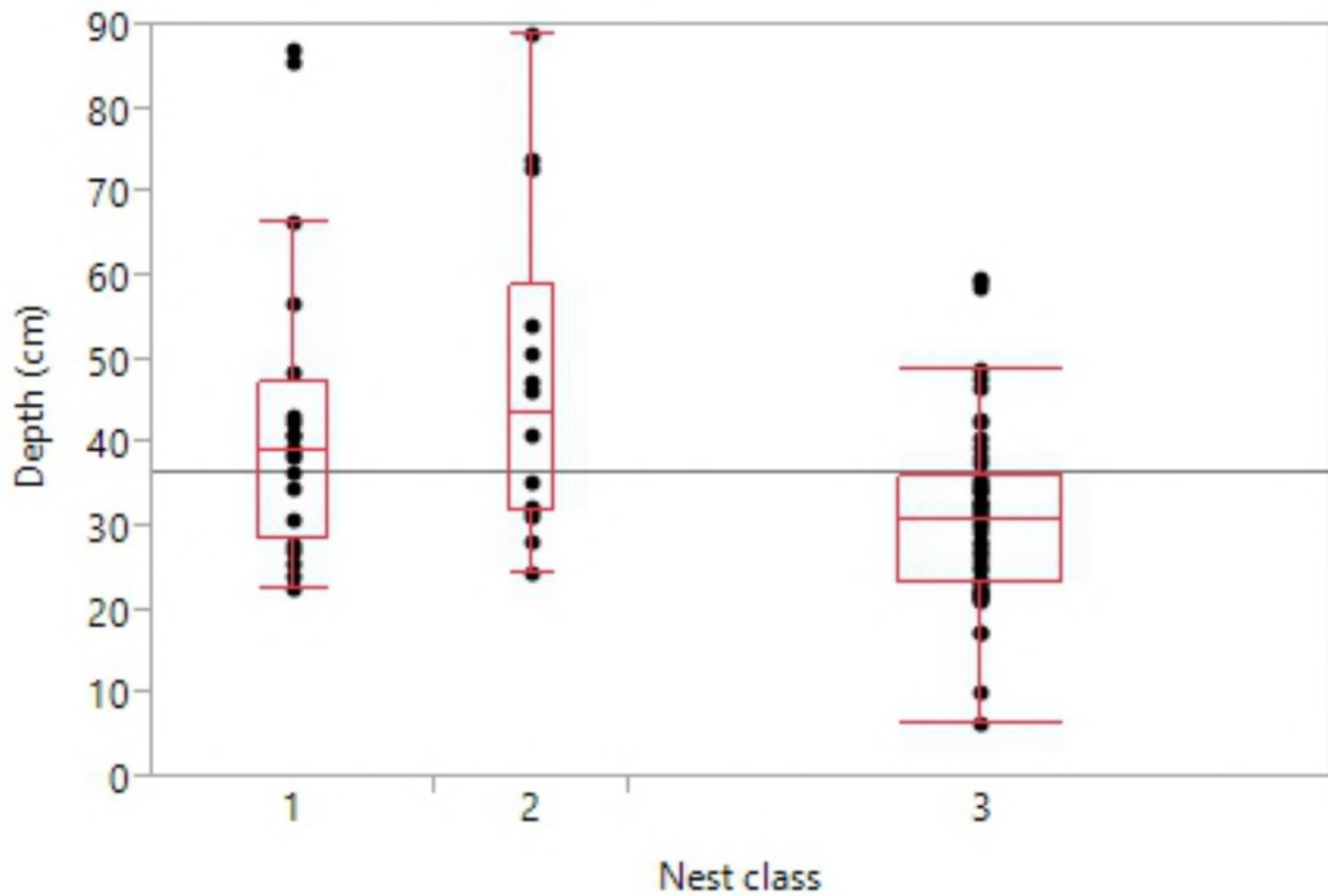
b)

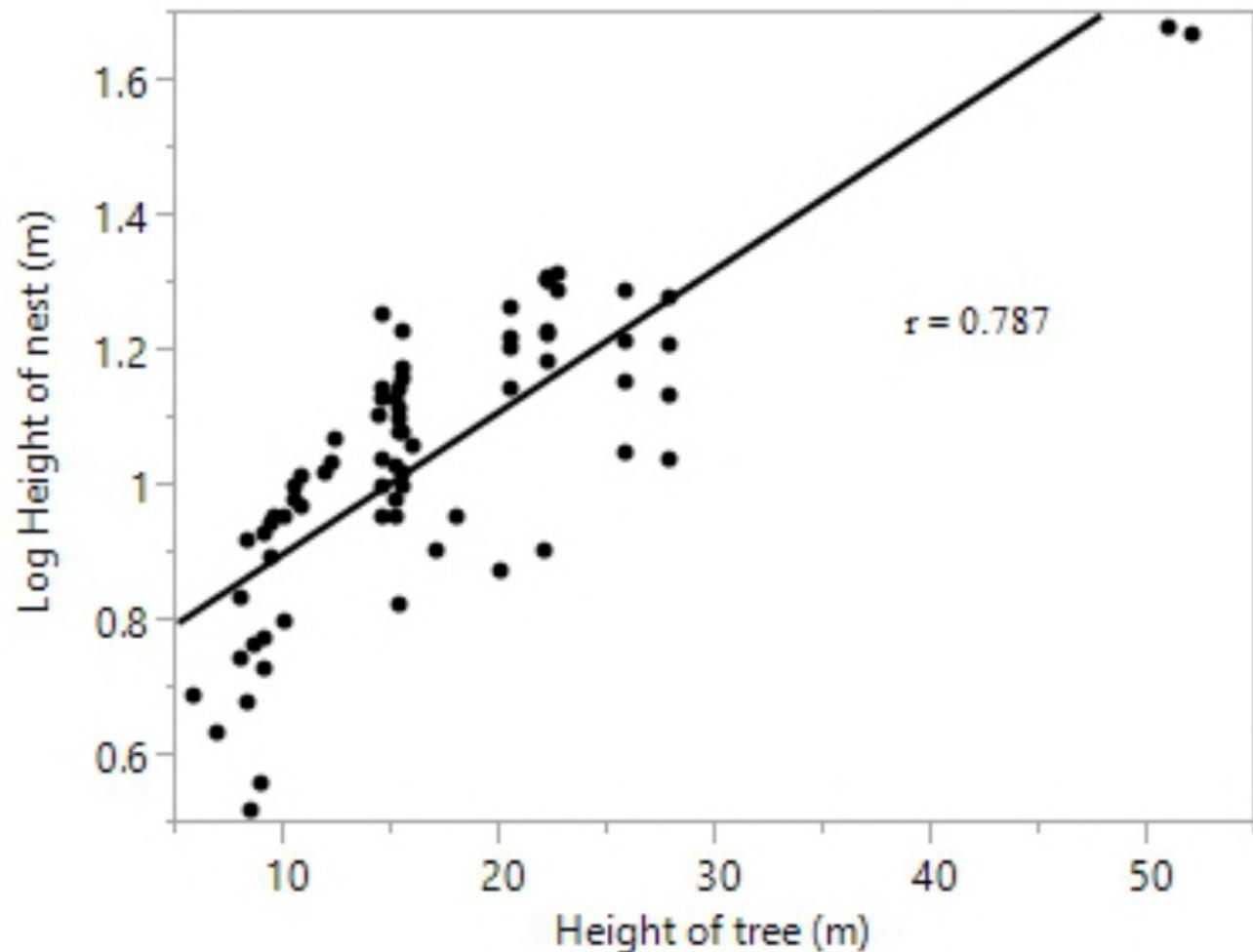


Closed
34.38%

Open
65.63%







Tree species

