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# 1 **Ecological Characterization of Syzygium (Myrtaceae) in Papua New Guinea**

2

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15

## 16 **Abstract**

17 Syzygium is the largest woody genus of flowering plants in the world and one of the most important components  
18 of the forest vegetation in Papua New Guinea (PNG). Although the systematics of the genus is improving, a  
19 comprehensive appraisal of the environmental features and gradients of its species is still lacking. Our work aims  
20 to fill this gap by analyzing the georeferenced specimens collected at the Lae National Herbarium of PNG. A  
21 data set of 1,563 records of 131 species was used to assess their altitudinal gradients and the correspondence  
22 with the main vegetation types and to model their spatial ecological niche with respect to climatic, topographical,  
23 and pedological variables. Several species were found to be widely distributed throughout the region, while other  
24 species were restricted to narrow altitudinal belts or only occurred in specific vegetation types. Overall, the  
25 genus is also characterized by an increasing altitudinal turnover likely due to topography-driven isolation. The  
26 improved knowledge of the ecological requirements of Syzygium assists in the elaboration of effective

27 conservation strategies and improves in situ species identification of this taxonomically difficult group.

28

## 29 **Keywords**

30 Topography-driven isolation, altitudinal gradients, *Syzygium*

31

## 32 **Introduction**

33 *Syzygium* R.Br. Ex Gaertn belongs to the Myrtaceae family and is the largest genus of woody flowering plants  
34 with about 1,200–1,800 species distributed throughout the Old-World tropics and subtropics [1, 2]. The greatest  
35 species diversity of *Syzygium* occurs in Southeastern Asia, Malesia, Northeastern Australia, and New Caledonia,  
36 while its greatest morphological and evolutionary diversity is within the Australian-Melanesian region [3, 4]. In  
37 Papua New Guinea (PNG), *Syzygium* is mainly represented by rainforest tree species widely distributed from  
38 the lowlands up to the highest elevations at about 4,000 m a.s.l. [5] presenting a broad variation of traits, even in  
39 response to abiotic factors, such as, for example, the degree of leaf venation in *S. Buettnerianum* along an  
40 altitudinal gradient [6]. Their flowers are important for a wide range of pollinators, while the fleshy and  
41 succulent fruits attract several mammals and birds. The first comprehensive review of *Syzygium* in PNG [6]  
42 recognized 138 species and more recent studies [7–11] have concluded that there are 207 species in the region,  
43 of which 84% are endemic [12]. However, the taxonomy of the genus remains a challenge, and uncertainties  
44 have been highlighted [13] and explored with in DNA studies [14]. Based on their results, Craven et al. [5]  
45 proposed the transfer to *Syzygium* of previously independent genera, such as *Acmena*, *Acmenosperma*,  
46 *Cleistocalyx*, *Piliocalyx*, and *Waterhousea*. Moreover, an infrageneric classification of the genus was presented  
47 as suggested by the inferred phylogeny [15]. In parallel with improvements in taxonomic knowledge, analyses  
48 on the spatial distribution and ecological preferences of *Syzygium* spp. In PNG are needed to support both  
49 forestry and conservation activities.

50 To achieve this aim, georeferenced *Syzygium* occurrences, held at the PNG National Herbarium of Lae (LAE),  
51 were analyzed with respect to pedological, climatic, altitudinal parameters and vegetation types.

52 **Material and Methods**

53 Data set

54 Lae hosts more than 2,000 specimens of *Syzygium* including information on latitude, longitude altitude,  
55 collection date, locality, and vegetation type. After checking for geographic and taxonomic inconsistencies, a  
56 final list of 131 species and 1,563 georeferenced records was obtained and used for analyses (table 1, figure 1).  
57 Environmental data include 19 bioclimatic variables, 3 soil variables, and slope. Climatic data were downloaded  
58 with a spatial resolution of 1 km from the Chelsa database [16], summarized in table 2. Soil data, such as organic  
59 carbon content, pH, and percentage of clay at 30 cm depth, were downloaded from SoilGrid [17] at 250 m spatial  
60 resolution. Slope was derived from a Digital Elevation Model with 90-m pixel resolution obtained from the  
61 NASA Shuttle Radar Topography Mission website.

62  
63 Data analysis

64 To assess the completeness of the *Syzygium* data set, held by LAE, the estimates of species richness obtained by  
65 the asymptotic Chao 2 estimator [18, 19] were compared with randomized species accumulation curves.

66 To evaluate the variation of the composition of *Syzygium* sp. in PNG along the altitudinal gradient, two tests  
67 were conducted. The first one was designed to assess the similarity among adjacent 100 m altitudinal belts using  
68 the Jaccard index and the second considered all possible combination between all couples of altitudinal belts.

69 Additionally, a detrended correspondence analysis was conducted to highlight the correspondence between  
70 altitudinal belts and *Syzygium* species. The correspondence between *Syzygium* species and vegetation types of  
71 the PNG forest map [20] was assessed using the indicator value index [21]. Vegetation types included coastal  
72 and swamp, lowland and montane forests, savanna and alpine grasslands, and heathlands.

73 A random forests (RF) model was used to model the spatial distribution of the *Syzygium* sp. with respect to  
74 climatic and soil variables. To this aim, only 40 *Syzygium* sp. with more than 10 occurrences were analyzed to  
75 reduce the uncertainties of the modeling procedure. To identify the most relevant variables in determining the  
76 distribution of *Syzygium* spp, the importance of the contribution of each variable accumulated along all nodes  
77 and all trees of the RF model were calculated [22].

78 Since the data set only contained presence data, in order to avoid overly optimistic predictions, pseudo-absences  
79 were estimated using random sampling without replacement, identifying a number of pseudo-absences equal to  
80 that of presences within known altitudinal ranges for the analyzed species. The quality for the fit of the model for  
81 each species was evaluated through the out-of-bag prediction error [23]. For each species, we repeatedly split the  
82 data in test and training sets. Each time, the model was built on the training set and used to predict the response  
83 on the test set, thus evaluating the prediction error. The average prediction error obtained was used for model  
84 evaluation. Probability distribution maps of the best model were then transformed into suitability maps by  
85 applying a threshold to each taxon to obtain a 0% omission error, which ensures that all the occurrences are  
86 correctly predicted. Data analysis was performed using the R statistical software [24] and geographical analysis  
87 was performed with QGIS software [25].

88

## 89 **Results**

90 The number of specimens collected during colonial times (before 1975) was higher compared with that collected  
91 afterward, even though a significant increase is expected in coming years due to the ongoing National Forest  
92 Inventory (figure 2). The difference between the sampling accumulation curve and the estimates produced by the  
93 Chao 2 estimator shows that a certain number of unknown species of *Syzygium* are yet to be collected and  
94 formally described (figure 3). Plotting the *Syzygium* samplings in the environmental space of PNG indicates that  
95 the genus mainly occupies warmer and drier areas characterized by annual precipitation below 3,000 mm and  
96 mean annual temperature above 20°C (figure 4). At higher elevations (using the altitudinal gradient), the  
97 similarity among altitudinal belts decreases significantly, in a linear way considering only adjacent belts (figure  
98 5) and nonlinearly considering all possible distances (figure 6). Altitudinal belts and vegetation types are  
99 characterized by different *Syzygium* species, from the lowland distributed *S. trivene* and *S. gonatanthum* to the  
100 alpine *S. alatum* and *S. benjaminum* (figure 7, table 3). Moreover, *Syzygium* species, for which sufficient  
101 occurrences were available for modeling purposes, showed different suitability areas ranging from very narrow,  
102 such as the case of *S. alatum*, to widely spread, as *S. amplum*, which potentially covers more the 50% of PNG  
103 (figure 8, table 3). Such potential distributions are mainly determined by temperature variables, particularly the

104 minimum temperature of coldest month (Bio6 ) and temperature seasonality (Bio4). Conversely, variables  
105 related to precipitation and soil parameters appeared to play a minor role (table 4).

106

## 107 **Discussion**

108 *Syzygium* is one of the most important tree genera of the PNG forest both in terms of biodiversity conservation,  
109 environmental integrity, and timber harvesting. Taxonomic knowledge has improved over time with 207 taxa  
110 currently recognized [12] and more species expected to be discovered [26]. However, knowledge about  
111 ecological features and environmental distribution is still incomplete. Despite the necessity to increase the field  
112 survey (figures 2 and 3), some preliminary patterns emerged. At the genus level, most specimens occupy drier  
113 and warmer areas of the country (figure 4). When looking at the altitudinal gradients, the nonlinear decrease of  
114 the similarity index among all belts seems to indicate the occurrence of widely distributed species, such as *S.*  
115 *malaccense* and *S. stipulare* (figure 6). However, the significant reduction of similarity among adjacent  
116 altitudinal belts seems to confirm the general pattern of increasing species turnover characterizing islands due to  
117 topography-driven isolation [27]. These patterns are determined by the differentiated spatial distribution of  
118 *Syzygium* species, confirming previous descriptions of vegetation types of PNG [28], with species widespread in  
119 lowland forest, *S. trivene* and *S. stipulare*, in the montane forest, *S. subalatum* and *S. adelphicum*, and in the  
120 alpine grasslands, *S. alatum* and *S. benjaminum* (figure 7, table 2). These species are characterized by different  
121 ecological niches and suitability areas as defined by the application of RF on a set of environmental variables  
122 (figure 8, table 3). The application of species distribution models on floristic data has already been applied in  
123 PNG, but previous attempts were based on aggregating data at the genus level significantly increasing the  
124 uncertainties of prediction [29]. Within a genus, species with very different environmental requirements can be  
125 found, as our study clearly indicates. Furthermore, this study confirms the usefulness of the analysis of  
126 herbarium data in support of biodiversity conservation strategies, also within the framework of the  
127 implementation of the REDD initiative in the country [30], and in facilitating the identification of species in  
128 the field for research investigation and forest management.

129

130 **Conclusion**

131 Knowledge of plant diversity in PNG is far from complete, with more detailed documentation of many species  
132 required and with many new species, to science, still to be identified and documented. This lack of knowledge  
133 has a significant negative impact on the elaboration of effective conservation strategies and on a more  
134 sustainable management of PNG forest ecosystems. The availability of herbarium data proved to be important  
135 for elucidating the habitat preference of *Syzygium* in PNG, when integrated with environmental data and  
136 modeling tools. Our case study focused on *Syzygium*, one of the richest genera in the country; through it,  
137 knowledge on the distribution and ecological features of its woody species has been significantly improved. The  
138 replicability of the proposed approach to other taxonomic groups, for which further studies are needed, is  
139 highlighted.

140  
141 **Case study questions**

- 142 1. How important are herbarium data to improve the knowledge of plant species and to identify  
143 biodiversity hot spots?
- 144 2. How can herbarium data be used to guide new field surveys?
- 145 3. How can herbarium data be analyzed by means of species distribution models to improve the ecological  
146 knowledge of plant species?

147  
148 **Author contributions**

149 Kipiro Qizac Damas defined the study, collected the herbarium data, and contributed to the discussion section.  
150 Silvio Cianciullo verified and evaluated the herbarium data, collected relevant environmental data, and  
151 conducted the modeling analysis. Riccardo Testolin and Alessio Farcomeni conducted the statistical analyses.  
152 Fabio Attorre prepared the preliminary draft of the manuscript. Michele De Sanctis, Abe Hitofumi, Vojtech  
153 Novotny, and Paul Dargusch reviewed, commented upon, and edited the manuscript.

154  
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158 of Technology, the PNG Forest Research Institute, and the New Guinea Binatang Research Centre.

159

## 160 **Competing interests**

161 The authors have declared that no competing interests exist. Paul Dargusch is a section editor at CSE. He was  
162 not involved in the review process of this article. Fabio Attorre is a guest editor of the Papua New Guinea's  
163 Forests special collection. He was not involved in the review process of this article.

164

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168

## 169 **Supporting information**

170 Table S1 contains herbarium data in Excel format, which support the findings of this study.

171

## 172 **References**

- 173 1. Parnell JA, Craven LA, Biffin E. Matters of Scale: Dealing With One of the Largest Genera of  
174 Angiosperms. In: Hodkinson TR, Parnell JAN, editors. *Reconstructing the Tree of Life: Taxonomy and*  
175 *Systematics of Species Rich Taxa 2007*. Boca Raton, FL: CRC Press; 2007. pp. 251–273.
- 176 2. Ahmad B, Baider C, Bernardini B et al. *Syzygium* (Myrtaceae): monographing a taxonomic giant via 22  
177 coordinated regional revisions. *Peer J Preprints*. 2016;4: e1930v1.
- 178 3. Frodin DG. History and concepts of big plant genera. *Taxon*. 2004;53(3): 753–776.
- 179 4. Craven L. Myrtaceae of Papua. In: Marshall J, Beehler BM, editors. *The Ecology of Papua*. Singapore:  
180 Periplus Editions; 2006. pp. 429–433.
- 181 5. Craven LA, Biffin E, Ashton PS. *Acmena*, *Acmenosperma*, *Cleistocalyx*, *Piliocalyx* and *Waterhousea*

- 182 formally transferred to *Syzygium* (Myrtaceae). *Blumea-Biodiversity, Evolution and Biogeography of*  
183 *Plants*. 2006;51(1): 131–142.
- 184 6. Hartley TG, Perry LM. A provisional key and enumeration of species of *Syzygium* (Myrtaceae) from  
185 Papuasias. *J Arnold Arbor*. 1973;54(2): 160–227.
- 186 7. Takeuchi W. Notes and new species in Papuan *Syzygium* (Myrtaceae). *Edinb J Bot*. 2002;59(2): 259.
- 187 8. Takeuchi W. *Syzygium snowianum* (Myrtaceae) a new canopy species from the Southern Escarpment of  
188 Papua New Guinea. *Phytotaxa*. 2015;2014: 80–84.
- 189 9. Snow N, Craven LA. Five new species of *Syzygium* (Myrtaceae) from New Guinea. *Harv Pap Bot*.  
190 2010;15(1):123–136.
- 191 10. Conn BJ, Damas KD. Notes on *Syzygium* (Myrtaceae) in Papua New Guinea. *Telopea*. 2015;18: 233–  
192 241.
- 193 11. Craven LA. Studies in Papuan *Syzygium* (Myrtaceae): 1. Subgenus *Perikion* revised. *Blumea-*  
194 *Biodiversity, Evolution and Biogeography of Plants*. 2019;64(2): 115–122.
- 195 12. Ca´mara-Leret R, Frodin DG, Adema F et al. New Guinea has the world’s richest island flora. *Nature*.  
196 2020; 584(7822): 579–583.
- 197 13. Craven LA. Unravelling Knots or Plaiting Rope: What Are the Major Taxonomic Strands in *Syzygium*  
198 *sens. lat.* (Myrtaceae) and What Should be Done With Them? In: Saw LG, Chua LSL, Khoo KC,  
199 editors. *Taxonomy: The Cornerstone of Biodiversity, Proceedings IV International Flora Malesiana*  
200 *Symposium*. Kuala Lumpur, Malaysia; 2001. pp. 75–85.
- 201 14. Biffin E, Craven LA, Crisp MD et al. Molecular systematics of *Syzygium* and allied genera (Myrtaceae):  
202 evidence from the chloroplast genome. *Taxon*. 2006;55(1): 79–94.
- 203 15. Craven LA, Biffin E. An infrageneric classification of *Syzygium* (Myrtaceae). *Blumea-Biodiversity,*  
204 *Evolution and Biogeography of Plants*. 2010;55(1): 94–99.
- 205 16. Karger DN, Conrad O, Boehner J et al. Climatologies at high resolution for the earth’s land surface  
206 areas. *Sci Data*. 2017;4(1): 1–20.
- 207 17. Hengl T, Mendes de Jesus J, Heuvelink GB et al. SoilGrids250 m: global gridded soil information based

- 208 on machine learning. PLoS One. 2017;12(2): e0169748.
- 209 18. Chao A. Estimating the population size for capture- recapture data with unequal catchability. Biometrics.
- 210 1987;43(4): 783–791.
- 211 19. Colwell RK, Coddington JA. Estimating terrestrial biodiversity through extrapolation. Philos Trans R
- 212 Soc Lond B Biol Sci. 1994;345(1311): 101–118.
- 213 20. Japan International Cooperation Agency and Papua New Guinea Forest Authority. Papua New Guinea
- 214 Forest Base Map 2012. Port Moresby, Papua New Guinea: Forest Inventory & Mapping Branch of PNG
- 215 Forest Authority head office; 2016. p. 8.
- 216 21. Dufrene M, Legendre P. Species assemblages and indicator species: the need for a flexible asymmetrical
- 217 approach. Ecol Monogr. 1997;67(3): 345–366.
- 218 22. Breiman L. Random forests. Mach Learn. 2001;45(1): 5–32.
- 219 23. Ciss S. Generalization Error and Out-of-bag Bounds in Random (Uniform) Forests. 2015. Available:
- 220 <https://hal.archives-ouvertes.fr/hal-01110524v2/document>.
- 221 24. R Core Team. R: a language and environment for statistical computing. Vienna, Austria: R Foundation
- 222 for Statistical Computing; 2017. Available: <https://www.R-project.org/>.
- 223 25. QGIS Development Team. QGIS Project. Chicago, IL: Open Source Geospatial Foundation Project;
- 224 2016.
- 225 26. Conn BJ, Damas KQ. Trees of Papua New Guinea. Xlibris. 2019;1–3: 416.
- 226 27. Steinbauer MJ, Field R, Grytnes JA et al. Topography-driven isolation, speciation and a global increase
- 227 of endemism with elevation. Glob Ecol Biogeogr. 2016;25(9): 1097–1107.
- 228 28. Goodland R, Paijmans K. New Guinea Vegetation. Brittonia. 1977;29(4): 432.
- 229 29. Hoover JD, Kumar S, James SA et al. Modeling hotspots of plant diversity in New Guinea. Trop Ecol.
- 230 2017;58: 623–640.
- 231 30. Grussu G, Attorre F, Mollicone D et al. Implementing REDD in Papua New Guinea: Can biodiversity
- 232 indicators be effectively integrated in PNG’s National Forest Inventory? Plant Biosystems. 2014;148(3):
- 233 519–528.

234 **Tables**235 **Table 1.** Syzygium species and number of specimens collected at the Lae National Herbarium. Nomenclature

236 follows Camara-Leret et al. [12].

<b>Species</b>	<b>n</b>	<b>Species</b>	<b>n</b>
Syzygium acuminatissimum	15	Syzygium nitidum	1
Syzygium acutangulum	24	Syzygium normanbiense	4
Syzygium adelphicum	41	Syzygium novoguineensis	1
Syzygium aeoranthum	3	Syzygium nutans	24
Syzygium alatum	34	Syzygium onesimum	3
Syzygium amplum	22	Syzygium pachycladum	20
Syzygium aqueum	49	Syzygium pallens	6
Syzygium attenuatum	4	Syzygium pergamaceum	10
Syzygium bauerlenii	3	Syzygium phaeostictum	4
Syzygium benjaminum	30	Syzygium platypodum	7
Syzygium bicolor	4	Syzygium plumeum	10
Syzygium branderhorstii	21	Syzygium pluviatile	3
Syzygium brassii	1	Syzygium porphyrocarpum	15
Syzygium buettnerianum	38	Syzygium pseudomegistophyllum	1
Syzygium burepense	1	Syzygium pteropodum	8
Syzygium busuense	8	Syzygium puberulum	13
Syzygium callianthum	3	Syzygium pullenii	2
Syzygium capituliferum	1	Syzygium pyriforme	3
Syzygium carrii	1	Syzygium pyrocarpum	9
Syzygium cauliflorum	18	Syzygium racemoides	1
Syzygium cinctum	1	Syzygium recurvovenosum	2

<i>Syzygium cladopterum</i>	1	<i>Syzygium richardsonianum</i>	28
<i>Syzygium claviflorum</i>	11	<i>Syzygium robbinsii</i>	2
<i>Syzygium coalitum</i>	10	<i>Syzygium romeri</i>	4
<i>Syzygium cratermontensis</i>	2	<i>Syzygium rosaceum</i>	6
<i>Syzygium dansiei</i>	1	<i>Syzygium roseum</i>	2
<i>Syzygium decipiens</i>	7	<i>Syzygium rubropunctatum</i>	1
<i>Syzygium delicatulum</i>	3	<i>Syzygium sabangense</i>	3
<i>Syzygium dolichophyllum</i>	8	<i>Syzygium saliciforme</i>	1
<i>Syzygium effusum</i>	87	<i>Syzygium samarangense</i>	29
<i>Syzygium erythropetalum</i>	12	<i>Syzygium sambogense</i>	2
<i>Syzygium fastigiatum</i>	7	<i>Syzygium saundersii</i>	3
<i>Syzygium fibrosum</i>	13	<i>Syzygium sayeri</i>	15
<i>Syzygium flavescens</i>	6	<i>Syzygium schumannianum</i>	4
<i>Syzygium flavidum</i>	1	<i>Syzygium sessiliflorum</i>	7
<i>Syzygium forte</i>	4	<i>Syzygium sogerense</i>	2
<i>Syzygium furfuraceum</i>	43	<i>Syzygium sp</i>	6
<i>Syzygium gonatanthum</i>	24	<i>Syzygium stipulare</i>	51
<i>Syzygium goniocalyx</i>	3	<i>Syzygium subalatum</i>	57
<i>Syzygium goniopterum</i>	6	<i>Syzygium subamplexicaule</i>	1
<i>Syzygium grandifolium</i>	2	<i>Syzygium subcorymbosum</i>	38
<i>Syzygium hemilamprum</i>	1	<i>Syzygium subglobosum</i>	1
<i>Syzygium hemilamprum hemilamprum</i>	3	<i>Syzygium suborbiculare</i>	3
<i>Syzygium heterobotrys</i>	1	<i>Syzygium sylvicola</i>	7
<i>Syzygium homichlophilum</i>	6	<i>Syzygium synaptoneurum</i>	2

<i>Syzygium hylochare</i>	8	<i>Syzygium taeniatum</i>	3
<i>Syzygium hylophilum</i>	53	<i>Syzygium thalassicum</i>	1
<i>Syzygium insulare</i>	5	<i>Syzygium thornei</i>	15
<i>Syzygium iteophyllum</i>	6	<i>Syzygium tierneyanum</i>	22
<i>Syzygium kipidamasii</i>	3	<i>Syzygium trachyanthum</i>	13
<i>Syzygium lagerstroemioides</i>	11	<i>Syzygium triphlebium</i>	2
<i>Syzygium laqueatum</i>	7	<i>Syzygium trivene</i>	73
<i>Syzygium leonhardii</i>	3	<i>Syzygium tympananthum</i>	1
<i>Syzygium leptoneurum</i>	3	<i>Syzygium uniflorum</i>	1
<i>Syzygium leptophlebium</i>	1	<i>Syzygium validinerve</i>	1
<i>Syzygium leptopodium</i>	26	<i>Syzygium variabile</i>	25
<i>Syzygium longipes</i>	37	<i>Syzygium verniciflorum</i>	4
<i>Syzygium lorentzianum</i>	10	<i>Syzygium vernicosum</i>	2
<i>Syzygium macrocalyx</i>	1	<i>Syzygium versteegii</i>	24
<i>Syzygium madangense</i>	1	<i>Syzygium viburnoides</i>	3
<i>Syzygium malaccense</i>	68	<i>Syzygium waikaiunense</i>	2
<i>Syzygium megalospermum</i>	8	<i>Syzygium waterhousei</i>	3
<i>Syzygium megistophyllum</i>	4	<i>Syzygium womersleyii</i>	36
<i>Syzygium montana</i>	11	<i>Syzygium xylopiaceum</i>	7
<i>Syzygium naiadum</i>	5	<i>Syzygium zhenghei</i>	38
<i>Syzygium nemorale</i>	10		

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**Table 2.** Climate variables from CHELSA database used to model.

	<b>Description</b>		<b>Description</b>
Bio1	Annual mean temperature	Bio11	Mean temperature of coldest quarter
Bio2	Mean diurnal range	Bio12	Annual precipitation
Bio3	Isothermality	Bio13	Precipitation of wettest month
Bio4	Temperature seasonality	Bio14	Precipitation of driest month
Bio5	Maximum temperature of warmest month	Bio15	Precipitation seasonality
Bio6	Minimum temperature of coldest month	Bio16	Precipitation of wettest quarter
Bio7	Temperature annual range	Bio17	Precipitation of driest quarter
Bio8	Mean temperature of wettest quarter	Bio18	Precipitation of warmest quarter
Bio9	Mean temperature of driest quarter	Bio19	Precipitation of coldest quarter
Bio10	Mean temperature of warmest quarter		

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242

243 **Table 3.** Syzygium species characterizing Papua New Guinea vegetation types based on indicator value analysis.

Species	Coastal	Swamp	Lowland	Savanna	Montane	Alpine
<i>Syzygium capituliferum</i>	x					
<i>Syzygium hemilamprum</i>	x					
<i>Syzygium onesimum</i>	x					
<i>Syzygium roemeri</i>	x					
<i>Syzygium rubropunctatum</i>	x					
<i>Syzygium versteegii</i>	x	x				
<i>Syzygium amplum</i>		x				
<i>Syzygium branderhorstii</i>		x	x			
<i>Syzygium heterobotrys</i>		x				
<i>Syzygium leptophlebium</i>		x				
<i>Syzygium recurvovenosum</i>		x				
<i>Syzygium uniflorum</i>		x				
<i>Syzygium acutangulum</i>			x			
<i>Syzygium aqueum</i>			x		x	
<i>Syzygium buettnerianum</i>			x			
<i>Syzygium effusum</i>			x		x	
<i>Syzygium furfuraceum</i>			x			
<i>Syzygium gonatanthum</i>			x			
<i>Syzygium hylophilum</i>			x			
<i>Syzygium longipes</i>			x			
<i>Syzygium lorentzianum</i>			x			
<i>Syzygium malaccense</i>			x			
<i>Syzygium megalospermum</i>			x			

Syzygium nemorale			x			
Syzygium nutans			x			
Syzygium pteropodum			x			
Syzygium richardsonianum			x		x	
Syzygium samarangense			x			
Syzygium stipulare			x			
Syzygium subcorymbosum			x			
Syzygium thornei			x			
Syzygium tierneyanum			x			
Syzygium trivene			x			
Syzygium brassii				x		
Syzygium coalitum				x		
Syzygium fibrosum				x		
Syzygium forte				x		
Syzygium puberulum				x		
Syzygium subamplexicaule				x		
Syzygium suborbiculare				x		
Syzygium adelphicum					x	x
Syzygium alatun					x	x
Syzygium benjaminum					x	x
Syzygium erythropetalum					x	
Syzygium laqueatum					x	
Syzygium leptopodium					x	
Syzygium montana					x	
Syzygium plumeum					x	

Syzygium porphyrocarpum					x	
Syzygium subalatum					x	
Syzygium sylvicola					x	
Syzygium variable					x	
Syzygium womersleyii					x	
Syzygium zhenghei					x	

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246 **Table 4.** Results of the Random Forests modeling on 40 *Syzygium* species with more than 10 occurrences.

<b>Species</b>	<b>N</b>	<b>Error %</b>	<b>Area%</b>	<b>Var1</b>	<b>Var2</b>	<b>Var3</b>
<i>Syzygium acuminatissimum</i>	15	54.8	50.0	bio4	Clay%	bio3
<i>Syzygium acutangulum</i>	24	22.3	30.9	bio2	bio7	bio6
<i>Syzygium adelphicum</i>	41	13.5	20.2	bio6	bio9	bio11
<i>Syzygium alatum</i>	34	8.4	8.9	bio6	bio9	bio5
<i>Syzygium amplum</i>	22	48.3	55.2	bio3	bio4	Slope
<i>Syzygium aqueum</i>	49	29.7	33.6	bio3	bio18	bio13
<i>Syzygium benjaminum</i>	30	13.4	13.4	bio6	bio8	bio11
<i>Syzygium branderhorstii</i>	21	18.8	33.6	bio11	bio6	bio1
<i>Syzygium buettnerianum</i>	38	33.5	40.2	bio13	bio16	bio4
<i>Syzygium cauliflorum</i>	18	29.7	34.1	bio13	bio16	bio17
<i>Syzygium claviflorum</i>	11	50.8	22.7	bio7	bio4	Org_C
<i>Syzygium effusum</i>	87	26.3	35.9	Slope	bio9	bio5
<i>Syzygium erythropetalum</i>	12	23.3	13.9	bio8	bio10	bio1
<i>Syzygium fibrosum</i>	13	18.8	16.2	bio15	bio14	bio10
<i>Syzygium furfuraceum</i>	43	32.4	36.3	bio15	bio4	bio3
<i>Syzygium gonatanthum</i>	24	30.8	14.6	bio8	bio18	bio4
<i>Syzygium hylophilum</i>	53	33.2	41.8	bio4	bio7	bio3
<i>Syzygium lagerstroemioides</i>	11	46.8	44.4	bio17	bio14	bio18
<i>Syzygium leptopodium</i>	26	21.8	15.9	bio13	bio6	bio16
<i>Syzygium longipes</i>	37	28.7	72.1	bio16	Org_C	bio13
<i>Syzygium malaccense</i>	68	32.3	53.0	bio4	bio3	Org_C
<i>Syzygium montana</i>	11	24.6	25.4	bio8	bio6	bio10
<i>Syzygium nutans</i>	24	33.5	63.2	bio13	bio15	bio16

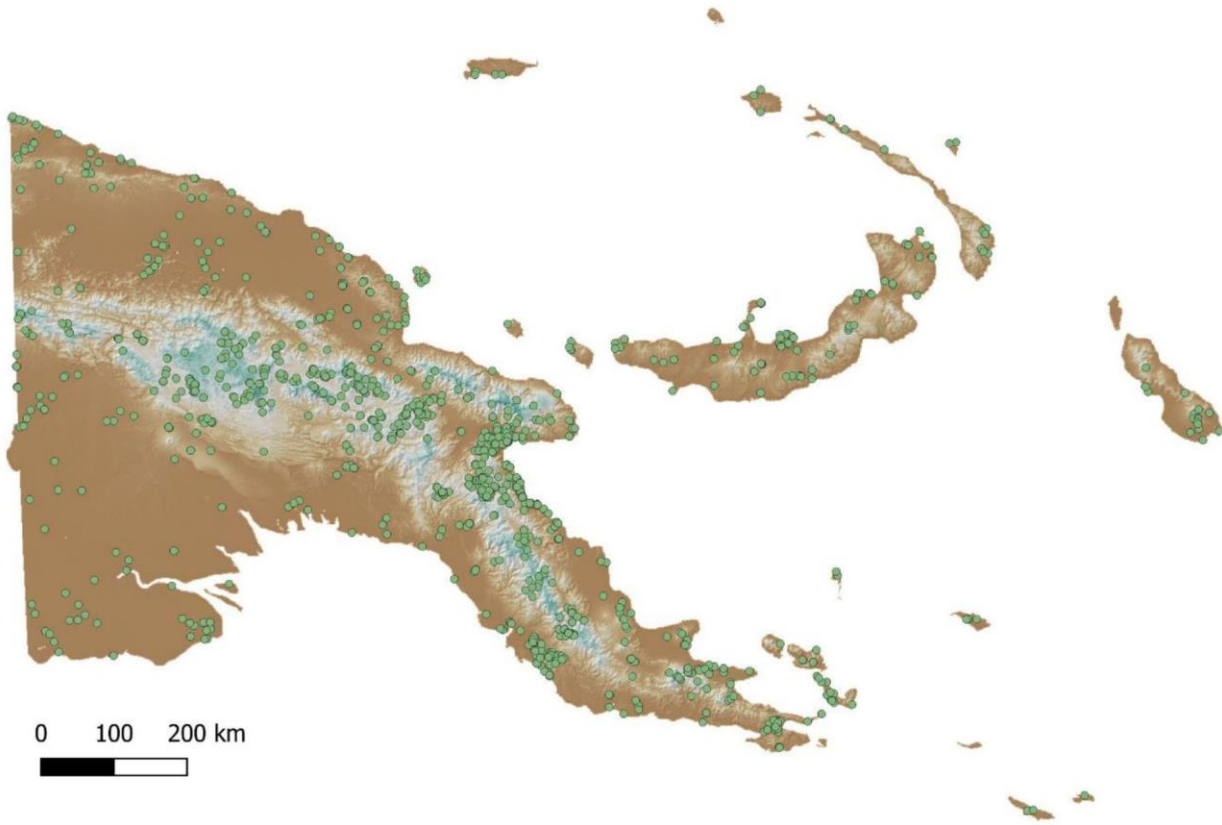
<i>Syzygium pachycladum</i>	20	39.3	28.1	bio3	bio4	Org_C
<i>Syzygium porphyrocarpum</i>	15	23.7	28.7	bio14	bio17	bio12
<i>Syzygium puberulum</i>	13	25.1	12.2	bio17	bio19	bio14
<i>Syzygium richardsonianum</i>	28	36.0	44.6	bio3	Clay%	bio4
<i>Syzygium samarangense</i>	29	12.3	16.8	bio7	bio2	bio6
<i>Syzygium sayeri</i>	15	35.5	22.1	bio18	bio8	bio13
<i>Syzygium stipulare</i>	51	31.0	55.6	bio4	bio3	Org_C
<i>Syzygium subalatum</i>	57	25.3	44.7	bio6	bio1	bio10
<i>Syzygium subcorymbosum</i>	38	22.6	53.9	bio9	bio10	bio6
<i>Syzygium thornei</i>	15	37.6	14.0	bio4	bio3	CEC
<i>Syzygium tierneyanum</i>	22	31.6	50.4	Clay%	bio7	bio2
<i>Syzygium trachyanthum</i>	13	39.8	32.7	bio16	CEC	bio13
<i>Syzygium trivene</i>	73	14.1	23.1	bio4	bio3	bio15
<i>Syzygium variable</i>	25	17.1	18.3	bio6	bio8	bio1
<i>Syzygium versteegii</i>	24	37.6	46.5	Slope	bio9	bio1
<i>Syzygium womersleyii</i>	36	20.9	24.5	bio6	bio9	bio11
<i>Syzygium zhenghei</i>	38	15.3	24.5	bio9	bio6	bio10

247 Note: N of occurrences, prediction error in percentage, potential suitable area in percentage and the first three

248 important environmental variables are reported. CEC ¼ exchangeable cation; Org\_C ¼ organic content.

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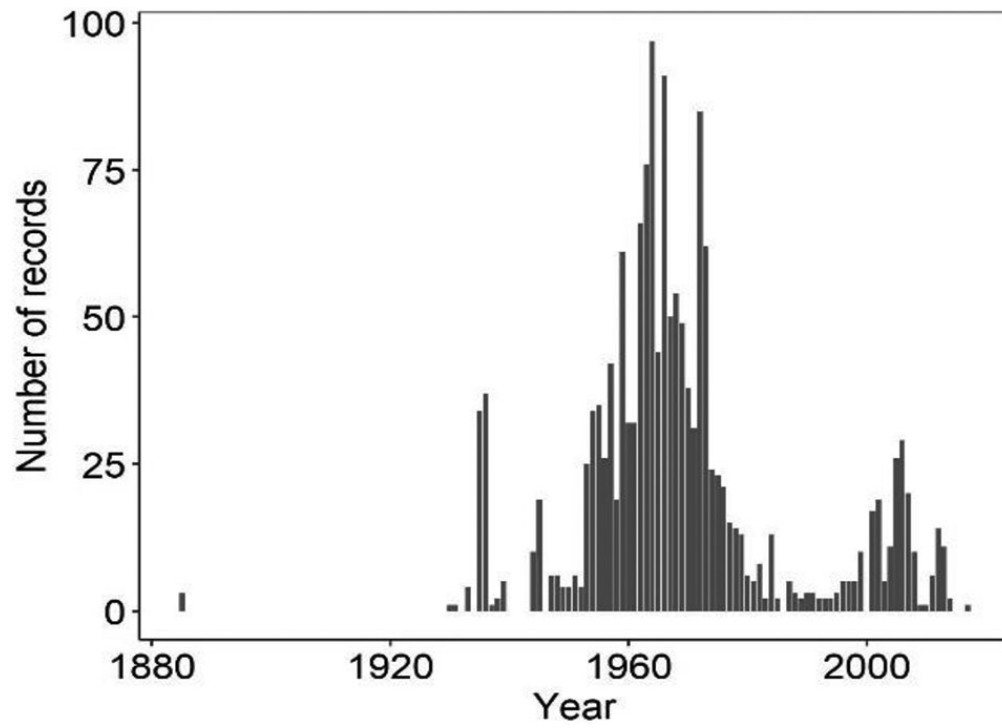
250 **Figures**



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252 **Figure 1.** Distribution map of the collections of *Syzygium* species as held at the Papua New Guinea National  
253 Herbarium (Lae). Refer data in table S1.

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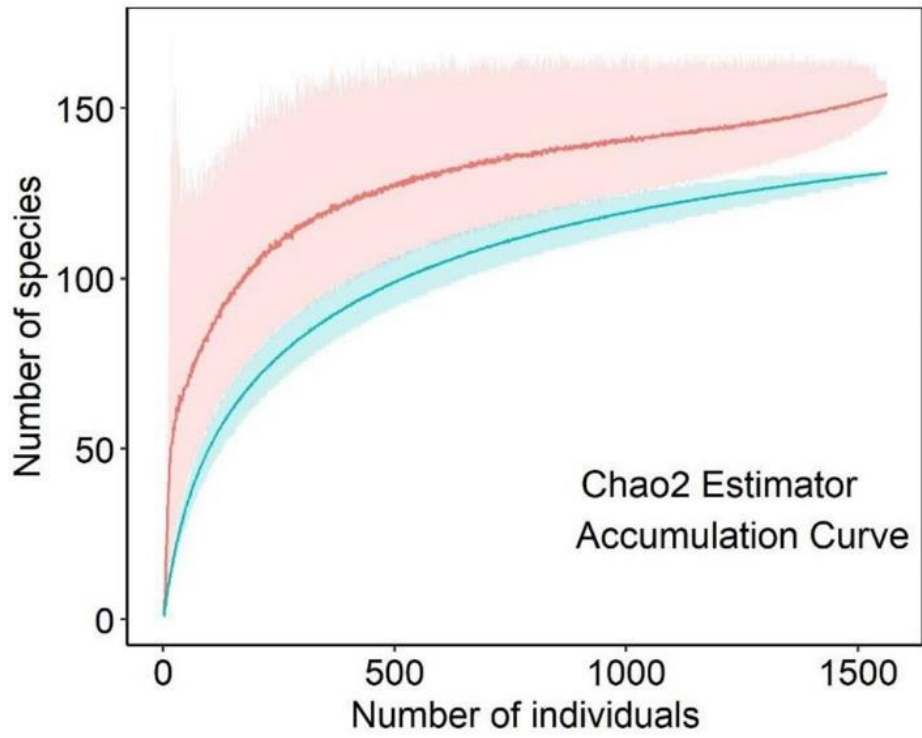


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256 **Figure 2.** *Syzygium* specimens collected at Lae National erbarium (Papua New Guinea) during the last 140

257 years.

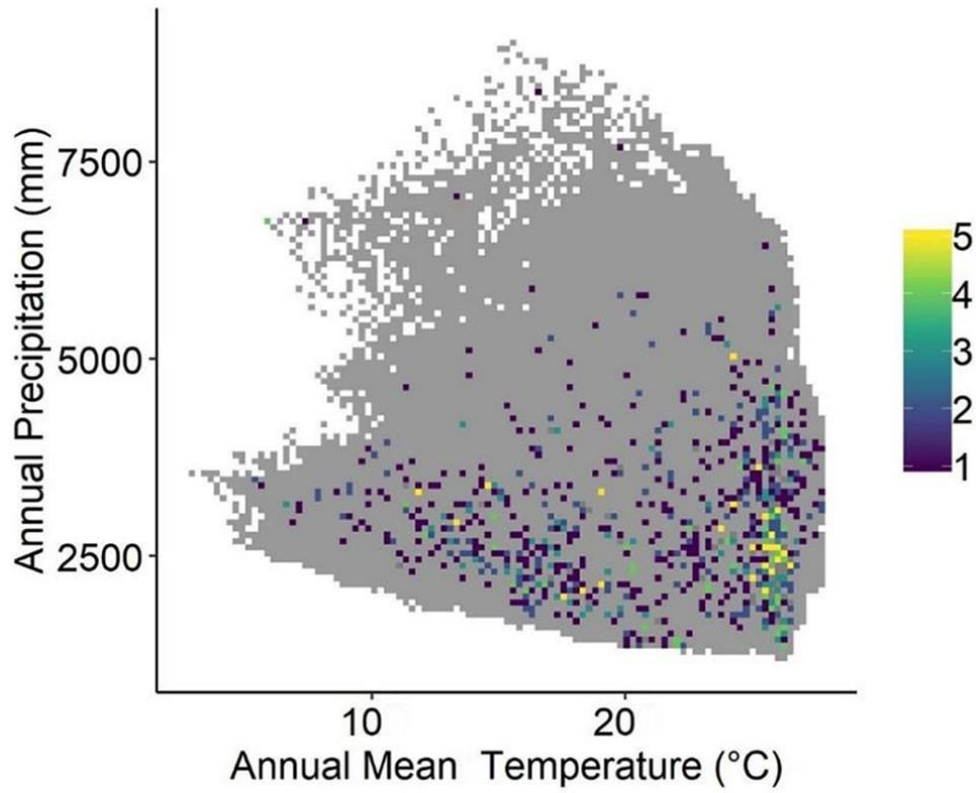
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260 **Figure 3.** Accumulation curve (blue) and estimates using Chao 2 estimator (red).

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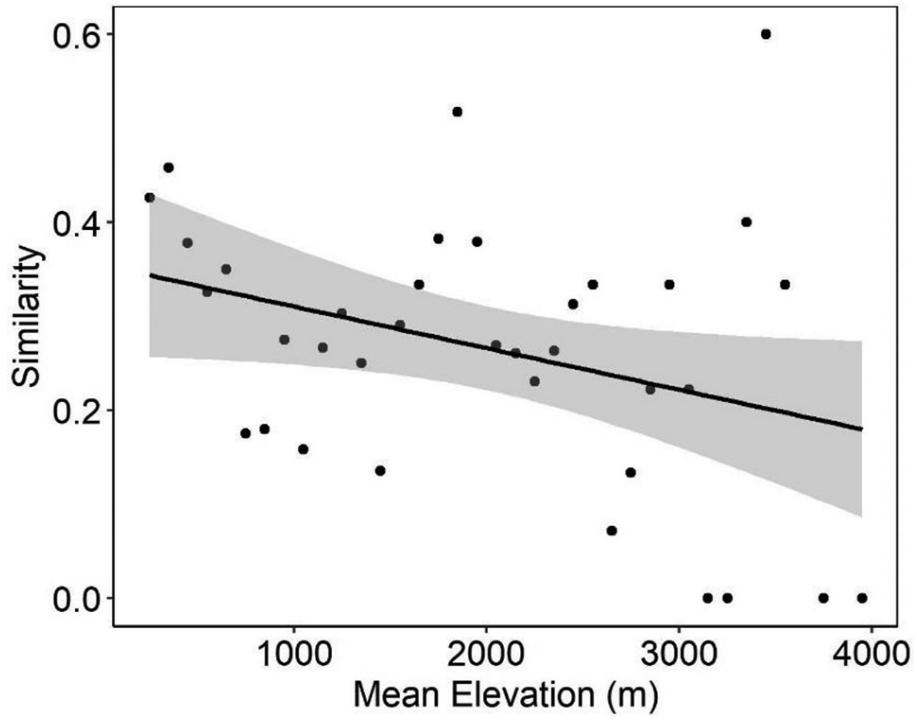
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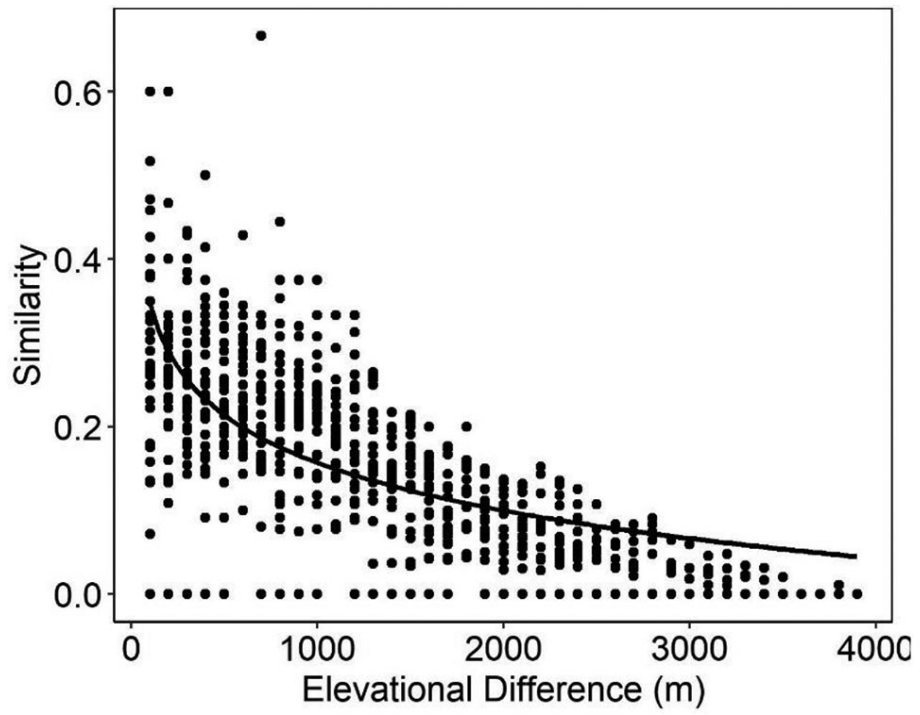
**Figure 4.** Scatterplot of Papua New Guinea environmental space as defined by annual precipitation and mean annual temperature (gray dots) and that occupied by *Syzygium* species grouped at genus level (purple to yellow according to the number of species per dot).



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268 **Figure 5.** Similarity among adjacent 100 m altitudinal belts measured using the Jaccard method.

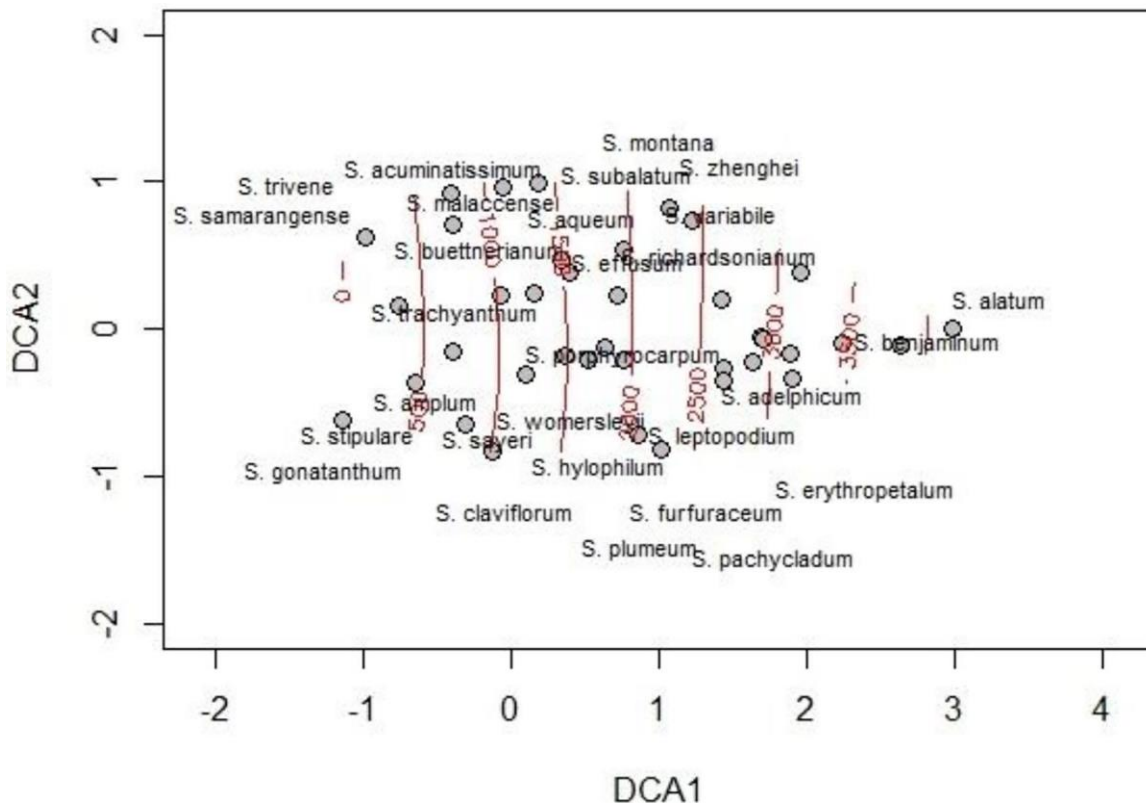
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271 **Figure 6.** Similarity between all possible couples of 100 m altitudinal belts measured using the Jaccard method.

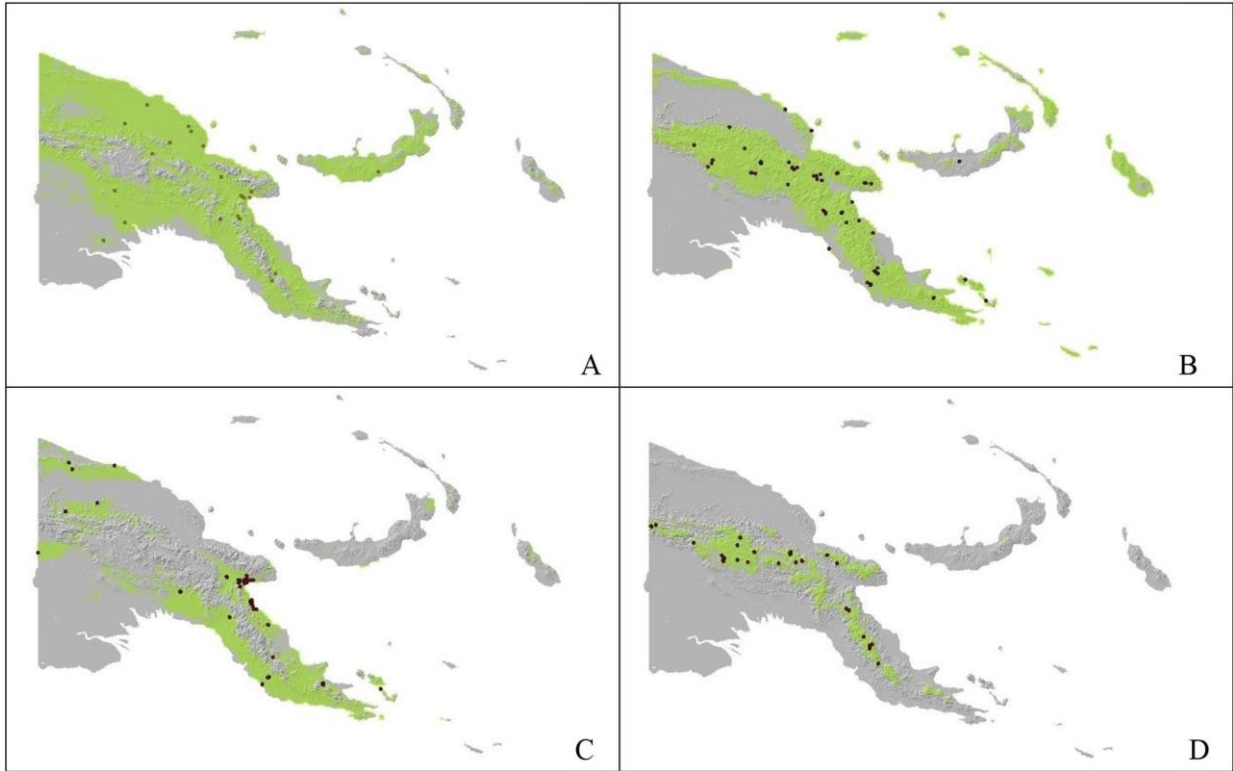
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274 **Figure 7.** Detrended correspondence analysis of altitudinal belts and their *Syzygium* species composition.

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277 **Figure 8.** Example of suitability areas (in green) as predicted by random forests of (A) *Syzygium amplum*, (B) *S.*  
 278 *subalatum*, (C) *S. trivene*, and (D) *S. alatum*. The black dots mark the occurrences for each species.