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Species Composition, Diversity and Distribution of Vascular Epiphytes in the Kihansi Gorge Forest, Tanzania

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Abstract

This study aimed at assessing the species composition, diversity and distribution of vascular epiphytes in the Kihansi Gorge Forest. Epiphytes sampling was conducted in twenty sampling plots established in the strip of riverine forest within the Kihansi Gorge. All vascular epiphytes growing on trees (phorophytes) rooted in the plots were sampled using ground-based technique as the method of access to the tree canopies. A total of 476 epiphyte individuals belonging to 20 species and 10 families were recorded in the study area. Among the twenty species recorded, *Drynaria laurentii* was the most abundant and most widely distributed in the study area. The epiphyte individuals were unevenly distributed within the twenty species. Epiphyte species richness and diversity was highest in KM transect and lowest in KS transect, while the epiphyte abundance was highest in KH transect. Along the phorophytes, 62% of the vascular epiphyte individuals occupied a zone upper than ten metres. In general, the Kihansi Gorge Forest is a home to twenty epiphyte species, dominated by ferns and orchids. The highest diversity in the study area was found in KM transect which was located at mid-elevation. On the phorophytes, higher abundance of epiphytes was found in the upper zone.

Keywords: Kihansi Gorge, Vascular epiphyte, Canopy, Diversity, Phorophyte.

Introduction

Epiphytes are plants that grow on other plants (usually on trees or shrubs) but without parasitising them (Benzing 1990, Hietz 1999, Zotz 2013, Getaneh and Gamo 2016). Epiphytes depend on support from their host plants (also known as phorophytes) and not nutrients or water. They normally grow attached to the trunks and branches of forest trees, shrubs, and lianas; some even on the surfaces of living leaves. They are the life forms mostly restricted to and typical of humid tropical forests (Richards 1996, Hietz 1999, Freitas et al. 2016). Epiphytes are relatively high light-demanding life forms, hence most of them occupy the tree canopy and very few epiphytes grow in the forests' undergrowths where the illumination is minimal. Epiphytes are ecologically important groups of plants, as they provide habitats and food to insects and birds (Benzing 1990, Nadkarni 1992, Stuntz et al. 2002, Fleming et al. 2004, de la Rosa-Manzano et al. 2017). In addition, epiphytes can be used by human beings for medical, agricultural and horticultural purposes (Nadkarni 1992). Moreover, epiphytes have important ecological values and contributions to forest biodiversity, such as increasing species diversity, primary productivity, biomass, litter fall and water retention. Moreover, epiphytes provide substrates for nitrogen fixing bacteria (Getaneh and Gamo 2016). Due to their high sensitivity to climate changes, epiphytes have been used as bioindicators of climate changes, pollution and ecological damage (Lugo and Scatena 1992, Benzing 1998, Getaneh and Gamo 2016). Based on their vascular systems, epiphytes can be classified into two major groups, namely vascular epiphytes and non-

vascular epiphytes. Vascular epiphytes are those with a vascular system, whereas non-vascular epiphytes are those with no vascular system. According to Benzing (1990), the vascular epiphytes include ferns, orchids and some other flowering plants while non-vascular epiphytes mainly consist of bryophytes and lichens.

Globally, vascular epiphytes comprise about 30000 species, which is about 10% of the earth's total vascular plants (Hietz 1999, Zotz 2013, Wang et al. 2016, de la Rosa-Manzano et al. 2017, Mohamed et al. 2017) and most of them are limited to tropical and subtropical forests, where they may be the most diverse life form (Gentry and Dodson 1987, Mohamed et al. 2017). Thus, high abundance of vascular epiphytes constitutes one of the remarkable characteristics of tropical forests. In some montane rain forests, vascular epiphytes may exceed 50% of local vascular plant species richness (Kelly et al. 2004). In lowland rain forests, epiphytes form a quarter of the entire flora (Gentry and Dodson 1987). Moreover, literature shows that epiphytes are very diverse in species, but only a few families are represented and that ferns and orchids dominate the epiphytic flora (Gentry and Dodson 1987, Krömer et al. 2005).

The present study on vascular epiphytes was conducted in the Kihansi Gorge Riverine Forest. Before this study, several studies on the vegetation of the Kihansi Gorge Forest had been conducted (Lovett et al. 1997, Quinn et al. 2005, Rija et al. 2011, Rija 2014, Vandvik et al. 2014). However, studies on the vascular epiphytes were limited and inadequate. Therefore, the aim of this study was to assess species composition, diversity and distribution of vascular epiphytes in the study area. Knowledge on the epiphyte species composition, diversity and distribution is essential for conservation and management of the species and their habitats. In this study the epiphyte species diversity was assessed as species richness and evenness or equitability. Species richness refers to the number of species in the community (Krebs 1989), while species evenness refers to the relative abundance of species (Magurran 1988). The distribution of vascular epiphytes in the study area was considered in two aspects, namely, horizontal distribution and vertical distribution (Kelly 1985). Horizontally, epiphytes distribution may vary among the forest types, while vertically along the phorophyte they can vary from the tree base to its top.

Materials and Methods

The study area

This study was conducted in the Kihansi Gorge Riverine (Kihansi River Gorge) Forest which is located in the southern escarpments of the Udzungwa Mountains, situated between latitudes 07º81´50´´ and 08º84´50´´ S and between longitudes 35º80´00´´ and 37º80´00´´ E. The Kihansi River Gorge, which is about 6 km long, runs north-south from an elevation of 300 m to 1100 m. It contains about 90 hectares of closed canopy forest, mostly consisting of mixed tree species (Lovett et al. 1997). The Udzungwa Mountains are a part of the Eastern Arc Mountains. According to Lovett (1998) the Eastern Arc Mountains are a chain of crystalline mountains that run from south-east Kenya to south-eastern Tanzania under direct climatic influence of the Indian Ocean. The Eastern Arc Mountains are considered to be one of the 25 global biodiversity hotspots.

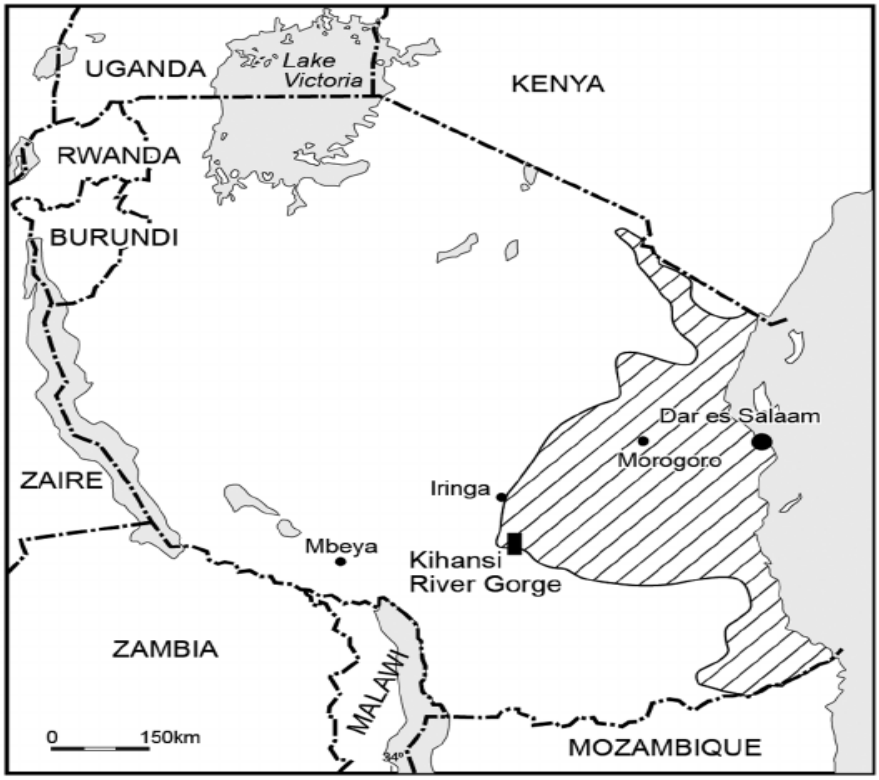

Figure 1: The map of Tanzania showing the location of the study area, the Kihansi River Gorge. Hatched area delimitates the region of the Eastern Arc Mountains and the coastal forests of Tanzania (Source: Vandvik et al. 2014).

Epiphyte sampling

Sampling of epiphytes was carried out in twenty permanent plots established in the Kihansi Gorge Riverine Forest. The field work was conducted in May 2004. Sampling plots (25 m x 25 m each) were established along five transects located at different positions, namely at the lower part of the gorge (KL transect), at the middle of the gorge (KM transect), at the upper part of the gorge (KH transect), in the spray zone (KS transect) and in the forest consisting of *Felicium* species only (KF transect). At each study site, all trees rooted into the plots were considered for epiphytes sampling. Ground-based technique was applied in which epiphytes were sampled from the forest floor using binocular for observation (Moffett 1993, Mohamed et al. 2017, Quaresma et al. 2017). Each phorophyte (host tree) was divided into two vertical zones (Johansson 1974) namely, zero to ten-metre zone and above ten-metre zone. A ten metre tall bamboo pole was used to demarcate the two zones. At each phorophyte, the pole was erected against the tree to demarcate the end of the ten-metre height. All epiphyte individuals found in each vertical zone were identified and their number counted. Horizontal distribution of vascular epiphytes was studied by assessing the species presence or absence in each of the twenty sampling plots. For epiphytes that could not be identified in the field, vegetative samples were collected or photographed using a zoom lens digital camera for identification in the herbarium at the University of Dar-es-Salaam.

Data analysis

Epiphyte species composition was determined by listing and counting all the species observed in the study area and epiphytes diversity was assessed as species richness and relative abundance of each species (evenness). Species richness was determined as number of species in the study area (Krebs 1989). The Shannon-Wiener's diversity index (H), as a measure of species diversity, was calculated using the following formula:

$$H = -\sum pi \ln pi,$$

where *H* is the diversity index, *pi* is a proportion that species i makes to total abundance, and *ln* is natural logarithm. Moreover, species evenness (E) was calculated to determine how individuals were distributed within the species (Magurran 1988) using the formula:

$$E = H/\ln S,$$

where, *E* is evenness, *H* is diversity index, *ln* is natural logarithm and *S* is total number of species. The horizontal distribution of each epiphyte species in the study area was determined as proportion of the number of plots in which a particular species was present relative to the total number of plots. The vertical distribution of epiphytes was determined by calculating the abundance (number of epiphyte individuals) in the two vertical zones of the phorophytes.

Results

Epiphyte species composition and diversity

A total of 476 epiphyte individuals belonging to twenty species were recorded on 59 phorophytes within the study area. The abundance or distribution of epiphyte individuals within the twenty species was highly uneven (evenness = 0.47). Among the species, *Drynaria laurentii* was the most abundant, with a total of 316 individuals, which was about 66% of all the epiphyte individuals sampled in the study sites. The remaining 19 species constituted only about 34% of all the individuals sampled. The four species, *Aerangis coriacea, Asplenium buettneri, Ficus lutea* and *Mohria coffrorum* were the least abundant, accounting for only 0.21% of the individuals each. The calculated Shannon-Wiener diversity index was 1.41.

The results further showed that among the twenty epiphyte species recorded, 11 (55%) belonged to ferns, 5 (25%) belonged to orchids and 4 (20%) belonged to other flowering plants. The results also indicated that the twenty epiphyte species sampled in the Kihansi Gorge Forest belonged to ten families. The ten families in which the epiphyte species belonged, their species composition and abundance are shown in Table 1.

Epiphyte species distribution in the study area

The results on the epiphyte species distribution in the study area (horizontal distribution) based on the species presence/absence data showed that *Drynaria laurentii* was the most widely distributed in the study area followed by *Ficus cyathistipula*, while *Aerangis coriacea, Asplenium buettneri, Ficus lutea* and *Mohria coffrorum Bulbophyllum cocleatum, Bulbophylum longiflorum, Bulbophyllum maximum, Calanthe sylivatica, Ctenitis lanuginose, Ficus lutea, Loranthus kayseri, Microsorum punctatum* and *Pleopeltis macrocarpa* had restricted range of distribution in the study area as shown in Figure 2 below.

Table 1: Summary results on the Kihansi Gorge epiphyte families: their species composition and abundance

Family	Number of species	Species names	Abundance
Orchidaceae	5	*Aerangis coriacea*	1
		Bulbophyllum cocleatum	2
		Bulbophylum longiflorum	2
		Bulbophyllum maximum	2
		Calanthe sylivatica	2
Aspidiaceae	1	*Ctenitis lanuginose*	7
Aspleniaceae	3	*Asplenium buettneri*	1
		Asplenium holstii	42
		Asplenium nidus	6
Moraceae	2	*Ficus cyathistipula*	10
		Ficus lutea	1
Loranthaceae	1	*Loranthus kayseri*	4
Polypodiaceae	4	*Drynaria laurentii*	316
		Phymatodes scolopendria	16
		Microsorum punctatum	2
		Pleopeltis macrocarpa	5
Piperaceae	1	*Peperomia molleri*	36
Adiantaceae	1	*Pallaea dominiana*	7
Psilotaceae	1	*Psilotum nudum*	13
Schizaceae	1	*Mohria coffrorum*	1

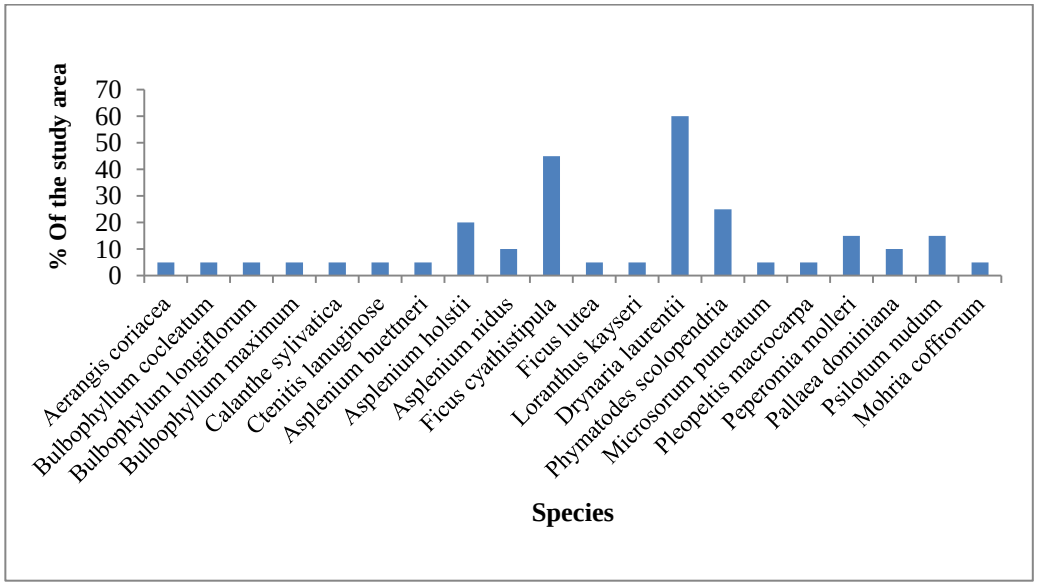

Figure 2: Epiphyte species distribution in the study area.

The vertical distribution of epiphytes along the phorophytes

Most of the epiphytes species showed no strict or clear restriction to any of the two vertical zones, hence most of them overlapped in the two vertical zones, i.e., they were found in both zones. However, species of family Polydiaceae were frequently found in the upper zone. Unlike the species richness, species abundance significantly varied vertically along the phorophytes. Among the 476 epiphyte individuals recorded in the Kihansi Gorge Forest, 185 individuals (38.87%) were found to occupy the lower (0 - 10 metres) zone on the phorophytes while 291 individuals (61.13%) were found to occupy the upper (above 10 metres) zone.

Comparison of the epiphyte species richness among the transects

The results of the comparison of epiphyte species richness across the five transects or study sites showed that the KM transect was the most species rich site followed by KH transect while KS transect was the least species rich site, as indicated in Figure 2.

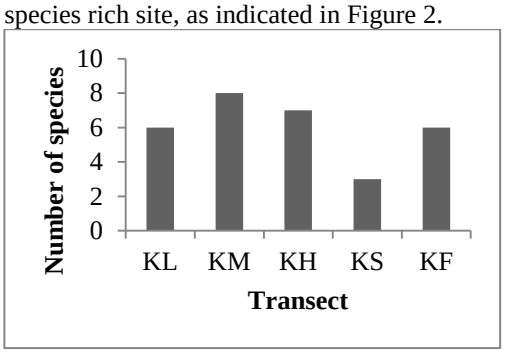

Figure 2: Comparison of epiphyte species richness among the transects.

Comparison of the epiphyte species abundance among the transects

Comparison of epiphyte species abundance across the study sites showed that KH transect was the most epiphyte-abundant transect and the other four transects had more or less equal numbers of epiphyte individuals, as indicated in Figure 3.

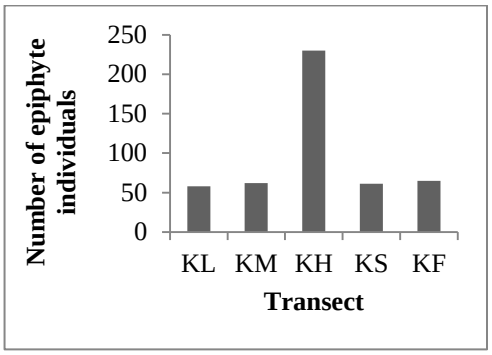

Figure 3: Comparison of epiphyte species abundance among the transects.

Comparison of the epiphyte species diversity among the transects

The comparison results showed that Shannon-Wiener diversity index was highest in KM site and lowest in KS site as indicated in Figure 4.

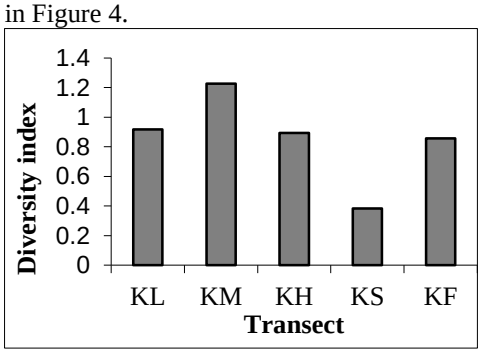

Figure 4: Comparison of epiphytes diversity (Shannon-Wiener diversity index) among the transects

Discussion

Epiphyte species diversity and horizontal distribution in Kihansi Gorge Forest

This study recorded a total of 476 epiphytes belonging to twenty species in the study area. The abundance or distribution of the epiphyte individuals within the twenty species was uneven, as 316 individuals (66% of all epiphyte individuals) recorded in this study belonged to a single species called *Drynaria laurentii* and the remaining 160 individuals (34%) belonged to the 19 species.

This resulted into low species evenness and consequently low species diversity (Shannon-Wiener Diversity index was 1.41). According to the results, the distribution of the 34% of the individuals within the 19 species was more or less even. The results of this study indicated that *Drynaria laurentii* was not only the most abundant, but also the most wide-spread epiphyte species in the study area. In this study, the species *Aerangis coriacea*, *Asplenium buettneri, Ficus lutea* and *Mohria coffrorum* were found to be the least abundant and had limited range of distribution in the study area, as they occurred in only 5% of the study area. The number of epiphyte species recorded in this study is low when compared to those recorded in studies conducted in different parts of the world. For example, in the studies conducted in French Guiana by Freiberg (1996) and Freiberg (1999), over fifty species of vascular epiphytes were recorded on a single tree.

The study revealed that the twenty epiphyte species recorded in this study belonged to only ten families, implying that epiphytes have many species but limited number of families. This observation seems to concur with the findings of several other studies conducted in different parts of the world (Gentry and Dodson 1987, Freitas et al. 2016, Mohamed et al. 2017). Literature shows that vascular epiphytes are distributed among 73 to 84 families worldwide (Zotz 2013). In the present study, the dominant families in the study area were Orchidaceae, Polydiaceae and Aspleniaceae. These families were also most diverse in terms of species composition. Orchidaceae was the most diverse family in the study area as it contained five species. The high diversity of Orchidaceae in the study area may be related to its high stress tolerance and its adaptive traits (Walter and Muller 1971). Normally orchids are adapted to temporary water stress and have ability to grow in drier and more-sun exposed areas of the upper canopy irrespective of the forest types. In terms of abundance, Polydiaceae was the most abundant family in the study area. In general, the epiphytic community in the Kihansi Gorge Forest was dominated by ferns and orchids which are the members of the families Polydiaceae and Orchidaceae, respectively. These finding are consistent with the findings of several other studies conducted in different tropical areas which show that Orchidaceae, Polydiaceae and Aspleniaceae are common families in tropical forests, including the studies by Gentry and Dodson (1987) and Mohamed et al. (2017).

Variations in epiphyte species richness, abundance and diversity among the transects

Comparison results on the species richness, abundance and diversity of vascular epiphytes among the five transects revealed existence of the variations in these parameters. The species richness and diversity of vascular epiphytes were highest in KM transect which was located at mid-elevation in the Kihansi Gorge Forest. Therefore, elevation or altitude is most likely to be among the factors influencing epiphyte species richness in the study area. The elevational gradient in vascular epiphyte diversity at local level has also been reported by Krömer et al. (2005) in their study conducted from the Amazonian lowlands to Timberline in the Andes. Similar to the findings of the this study, the studies by Küper et al. (2004) and Mohamed et al. (2017) also reported a high species richness at mid-elevation. On the other hand, the abundance of vascular epiphytes was highest in KH transect followed by KF transect. High abundance of vascular epiphytes in these transects can be related to availability of relatively large proportion of big trees, as most of the epiphytes in the study area seemed to prefer large trees, particularly those with rough barks. In Kihansi Gorge Forest, big trees carried more biomass of vascular epiphytes and some species, such as *Ficus cyathistipula* seemed to be restricted to big trees. This observation is similar to what were reported in the studies by de Andrade Kersten et al. (2009) and Mohamed et al. (2017). High

abundance of epiphytes on larger trees is probably due to the fact that such trees are likely to be older, hence allowing more time to capture epiphyte seeds or spores (Cummings et al. 2006) while small and young trees are not strong enough to support large number of epiphytes, and normally have smooth bark which may be not suitable for epiphytes colonization.

Vertical distribution of the vascular epiphytes

The abundance of vascular epiphytes in the study area showed uneven vertical distribution in the two vertical zones of the phorophytes. That is, there was unequal distribution of epiphytes along the vertical column of the phorophytes in which majority (61.13%) of the epiphyte individuals occupied the upper zone or stratum of the phorophytes. Stratification in vertical distribution of epiphytes on phorophytes was also reported by de Andrade Kersten et al. (2009), de la Rosa-Manzano et al. (2017) and Mohamed et al. (2017). Although most of the epiphyte species did not show strict preference of any of the two vertical zones of the phorophytes, species of family Polydiaceae frequently occupied the upper stratum. The observed variations in epiphytes abundance are probably due to variations in microclimatic conditions along the phorophytes (Woods et al. 2015, Getaneh and Gamo 2016). Contrary to the findings of this study, the study by Mohamed et al. (2017) conducted in Wondo Genet Natural forest in Ethiopia revealed that both species abundance and species richness of vascular epiphytes show vertical stratifications. They indicated that the vascular epiphytes increased from base to trunk to canopy. However, this was contrary to the findings of the study by Wang et al. (2016) who found that both abundance and species richness of vascular epiphytes decrease from trunk zone to inner crown zone to middle zone to outer crown zone. Generally, studies show that stratification in epiphytes vertical distribution is the result of vertical environmental variances existing from the forest floor to the canopy (Johansson 1974, Kelly 1985, Woods et al. 2015). According to Benzing (1995), the key environmental factors that influence the pattern of epiphytes distribution include temperature, moisture and light incidence.

Conclusion

The Kihansi Gorge Forest harbours twenty species of vascular epiphytes, which belong to ten families. Among the species, *Drynaria laurentii* was the most abundant and most widely distributed in the study area. The epiphytic community in the study area was dominated by ferns and orchids. Within the study area the maximum epiphyte species diversity was found in KM transect which was located at mid-elevation and vertically along the phorophytes the upper zone of the phorophytes harboured higher abundance of epiphytes than the lower zone. Altitude or elevation and microclimatic conditions are most likely to be the main factors influencing epiphytes distribution in the study area.

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References

Benzing DH 1990 Vascular Epiphytes. Cambridge University Press, Cambridge, UK.

Benzing HD 1995 Vascular Epiphytes. *In:* Lowman MD and Nadkarni NM (ed) *Forest Canopies*. Academic Press, New York.

Benzing DH 1998 Vulnerabilities of tropical forests to climate change: the significance of resident epiphytes. *Climatic Change* 39 (2-3): 519-540.

Cummings J, Martin M and Rogers A 2006 Quantifying the abundance of four large epiphytic fern species in remnant complex notophyll vine forest on the Atherton

Tableland, North Queensland, Australia. *Cunninghamia* 9(4): 521-527.

de Andrade Kersten, R, Borgo M and Silva SM 2009 Diversity and distribution of vascular epiphytes in an insular Brazilian coastal forest. *Rev. Biol. Trop.* 57: 749-759.

de la Rosa-Manzano E, Guerra-Pérez A, Mendieta-Leiva G, Mora-Olivo A, Martínez-Ávalos JG, and Arellano-Méndez LU 2017 Vascular epiphyte diversity in two forest types of the "El Cielo" Biosphere Reserve, Mexico. *Botany* 95: 599-610.

Fleming TH, Muchhala NC, Ornelas JF 2004 New World nectar-feeding vertebrates: community patterns and processes. *In* Sanchez-Cordero, V and Medellin RA (eds.) Contribuciones Mastozoologicas en Homenaje a Bernardo Villa, p.163.

Freiberg M 1996 Spatial distribution of vascular epiphytes on three emergent canopy trees in French Guiana. *Biotropica* 28: 345-355.

Freiberg M 1999 Vascular epiphytes on a *Virola michelii* tree (Myristicaceae) in French Guiana. *Ecotropica* 5: 75-81.

Freitas L, Salino A, Neto LM, Almeida TE, Mortara SR, Stehmann JR, Amorim AM, Guimarães EF, Coelho MN, Zanin A, Forzza RC 2016 A comprehensive checklist of vascular epiphytes of the Atlantic Forest reveals outstanding endemic rates. *PhytoKeys* 58: 65-79.

Gentry AH and Dodson CH 1987 Diversity and biogeography of neotropical vascular epiphytes. *Annuals of the Missouri Botanical Garden* 74: 205-233.

Getaneh ZA and Gamo FW 2016 Vascular epiphytes in Doshke and Kurpaye: A comparative study, Gamo Gofa, Ethiopia. *Int. J. Biodivers*. doi.org/10.1155/2016/9482057.

Hietz P 1999 Diversity and conservation of epiphytes in a changing environment. *Proceedings of the International Conference on Biodiversity and Bioresources Conservation and Utilization*. IUPAC: 23-27 November 1997, Phuket, Thailand.

Johansson, DR 1974 *Ecology of vascular epiphytes in West African rain-forest*. Doctoral dissertation, Sv. växtgeografiska sällsk.

Kelly DL 1985 Epiphytes and climbers of a Jamaican rainforest: vertical distribution, life forms and life histories. *J. Biogeogr*. 12: 223-241.

Kelly DL, O'Donovan G, Feehan J, Murphy S, Drangeid SO, Marcano-Berti L 2004 The epiphyte communities of a montane rain forest in the Andes of Venezuela: patterns in the distribution of the flora. *J. Trop. Ecol*. 20: 643-666.

Krebs CJ 1989 Ecological Methodology. Haper-Collins Publishers, New York.

Krömer T, Kessler M, Gradstein SR and Acebey A 2005 Diversity patterns of vascularepiphytes along an elevational gradient in the Andes *J. Biogeogr*. 32: 1799-1809.

Küper W, Kreft H, Nieder J, Körter N, Bartholott W 2004 Large-scale diversity patterns of vascular epiphytes in Neotropical montane rain forests. *J. Biogeogr*. 31: 1477-1487.

Lovett JC Hatton J, Mwasumbi LB and Gerstle JH 1997 Assessment of the impact of Lower Kihansi Hydropower Project on the forests of Kihansi Gorge, Tanzania. *Biodiversity and Conservation* 6: 915-933.

Lovett JC 1998 Importance of the Eastern Arc Mountains for vascular plants. *J. East Afr. Nat. Hist.* 87: 59-74.

Lugo AE and Scatena FN 1992 Epiphytes and climate change research in the Caribbean: a proposal. *Selbyana* 13: 123-130.

Magurran AE 1988 Ecological diversity and its measurement. Croom Helm, London.

Moffett MW 1993 The High Frontier: Exploring the tropical rain forest canopy. Havard University Press, Cambridge Massachusetts, USA.

Mohamed E, Kebebew M and Awas T 2017 Diversity of vascular epiphytes in wondo

genet natural forest, Southern Ethiopia. *Int. Res. J. Biol. Sci*. 6(2): 5-15.

Nadkarni NM 1992 The conservation of epiphytes and their habitats: Summary of a discussion at the international symposium on the biology and conservation of epiphytes. *Selbyana* 13: 140-142.

Quaresma AC, Piedade MTF, Feitosa YO, Wittmann F and Steege H 2017 Composition, diversity and structure of vascular epiphytes in two contrasting central Amazonian floodplain ecosystems. *Acta Bot. Brasil.* 31(4): 686-697.

Quinn CH, Ndangalasi HJ, Gerstle J and Lovett JC 2005 Effect of the Lower Kihansi Hydropower Project and post-project mitigation measures on wetland vegetation in Kihansi Gorge, Tanzania. *Biodivers. Conserv.* 14 (2): 297-308.

Richards PW (Ed.) 1996 Tropical Rain Forests (2nd ed). Cambridge University Press, Cambridge.

Rija AA 2014 Seed Predation and plant recruitment in an endangered *Coffea kihansiensis*. Project report submitted to the Rufford Small Grant Foundation, UK.

Rija AA, Mwamende KA and Hassan SN 2011 The aftermath of environmental disturbance on the critically endangered *Coffea kihansiensis* in the Southern Udzungwa Mountains, Tanzania. *Trop. Conserv. Sci.* 4(3): 359-372.

Stuntz S, Ziegler C, Simon U and Zotz G 2002 Diversity and structure of the arthropod fauna within three canopy epiphyte species in central Panama. *J. Trop. Ecol*. 18: 161-176.

Vandvik V, Maren IE, Ndangalasi HJ, Taplin J, Mbago F, and Lovett JC 2014 Back to Africa: monitoring post-hydropower restoration to facilitate reintroduction of an extinct-in-the-wild amphibian. *Ecosphere* 5(8): 95.

Walter H and Mueller DD 1971 Ecology of tropical and subtropical vegetation: Ecology of tropical and subtropical vegetation, Oliver and Boyd, Edinburgh.

Wang X, Long W, Schamp BS, Yang X, Kang Y, Xie Z and Xiong M 2016 Vascular epiphyte diversity differs with host crown zone and diameter, but not orientation in a Tropical Cloud Forest. *PloS one* 11(7): p.e0158548.

Woods CL, Cardelús CL, DeWalt SJ 2015 Microhabitat associations of vascular epiphytes in a wet tropical forest canopy. *J. Ecol*. 103: 421-430.

Zotz G 2013 The systematic distribution of vascular epiphytes - a critical update. *Bot. J. Linn. Soc.* 171: 453-481.