Sub-Saharan Botanical Collections
Demissew, Sebsebe; Beentje, Henk; Cheek, Martin; Friis, Ib

Published in:
Tropical Plant Collections: Legacies from the Past? Essential Tools for the Future?

Publication date:
2017

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Tropical Plant Collections: Legacies from the Past? Essential Tools for the Future?

Proceedings of an international symposium held by The Royal Danish Academy of Sciences and Letters in Copenhagen, 19th–21st of May, 2015

Edited by Ib Friis and Henrik Balslev
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Dedication

We dedicate this volume to the memory of Kai Larsen (1926-2012) and Gunnar Seidenfaden (1908-2001), both members of the Royal Danish Academy of Sciences and Letters and deeply committed to the study of tropical plants. They were always convinced that Danish scientists should play a role in the study of botany in the tropics, and they inspired and encouraged us in our work in South America, Africa and South East Asia.
Sub-Saharan Botanical Collections: Taxonomic research and impediments

Sebsebe Demissew, Henk Beentje, Martin Cheek and Ib Friis

Abstract

Many historical specimens from sub-Saharan Africa are only found in European herbaria, but a higher number of newer specimens than widely assumed are kept in African herbaria, with a concentration in eastern and southern parts of the continent. Many of these herbaria were initiated in connection with independence of former European colonies in Africa, fewer were built on well-established herbaria from the colonial period. There are many gaps in collecting coverage, not least with regard to areas of high plant diversity; this is often caused by poor access or political instability. High species diversity exists in both humid and arid parts of Africa. Lack of collections from and knowledge about areas of high species diversity makes it difficult to prioritise conservation efforts. Gaps in taxonomic knowledge exist in certain large families, such as Rubiaceae, or in large genera, such as Cyphostemma (Vitaceae), Euphorbia (Euphorbiaceae), Ipomoea (Convolvulaceae), Polystachya (Orchidaceae), and Barleria (Acanthaceae). Newly collected specimens are now mainly kept in African herbaria, but lack of training and resources in tropical African herbaria are important challenges to prevent African botanists from continuing a somewhat declining European activity, partly caused by the downgrading in priority given to herbaria in European universities and research institutions. Encouraging examples of progress are the many regional African floras that have now been finished or nearly finished in collaboration between African and European herbaria, and the increasing digitization of herbaria and the general development of relevant services on the Internet, which provides new possibilities for botanical studies in Africa.

Key Words: biodiversity hotspots, conservation, field work, herbaria, historical collections, tropical Africa, South Africa

Sebsebe Demissew, The National Herbarium, Department of Plant Biology and Biodiversity, Addis Ababa University, P.O. Box 3434; Gullele Botanic Garden, P.O Box 153/1029, Addis Ababa, Ethiopia. E-mail: sebseb.demissew@gmail.com

Henk Beentje, Royal Botanic Gardens, Kew, TW9 3AE, England, UK. E-mail: h.beentje@kew.org

Martin Cheek, Royal Botanic Gardens, Kew, TW9 3AE, England, UK. E-mail: m.cheek@kew.org

Ib Friis, Natural History Museum of Denmark, Universitetsparken 15, DK-2100 Copenhagen Ø, Denmark. E-mail: ibf@snm.ku.dk

**Historical Collections**

The oldest sub-Saharan plant collections date back to the 1670-1690s, with early collectors such as Patric Adair (Johanna Island = Anjouan), Edward Bartar (Ghana), Charles Coombs (Calabar in Nigeria), and John Kirckwood (Angola and Cabinda: Cabo Verde in Cape Verde Islands and Calabar in Nigeria), but most of the early collections come from the Cape of Good Hope in South Africa and were collected by Adair, William Dampier, John Fox, Paul Hermann, George Lewis, Frederick Ruysch, George Stonestreet...

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**Fig. 1.** The route of the travels of J.H. Speke and J.A. Grant from Zanzibar through Tanzania and Uganda in 1860-1863. Map published with Grant and Oliver (1872).
Most of the early collections were made along the coast. Apart from travels in Ethiopia and South Africa and attempts to cross the Sahara from the North (see for example Onana \textit{et al.} 2017) the first long inland journey that involved collecting of plants was that in 1860–1863 of J.H. Speke and J.A. Grant from Zanzibar along the Nile to Cairo (Fig. 1).

In the 18th and 19th centuries most collections of plants in sub-Saharan Africa were done by naturalists funded by European countries, institutions, or by individuals with the intention to explore territories unknown to Europeans. All collections of these travellers were deposited in institutions in Europe (Table 1). There were no academic institutions dealing with botany, or indeed any herbarium collections, in sub-Saharan Africa before 1870.

Three 19th century collectors deserve special mentioning because of their particularly large output of collections made during long residences or extended travelling in Tropical Africa: Schimper, Welwitsch and Schweinfurth. Not only did they make many collections in tropical Africa, their collections included
Table 1. Examples of historical collections of tropical African plants made before the 20th century and the herbaria where these specimens are deposited. Based on information from *Index Herbariorum* (Thiers continuously updated) and the index of collectors in *Index Herbariorum, Part II* (Lanjouw & Stafleu 1954, 1957; Chaudhri et al. 1972; Vegter 1976, 1983, 1986, 1988), updated with http://plants.jstor.org/. Schweinfurth’s data have been supplemented from Wickens (1972). Most of the material brought out of Ethiopia by Bruce were drawings and seeds and bulbs; the few extant herbarium specimens were prepared from plants cultivated in various gardens in Europe (Hulton et al. 1991). Speke and Grant, Hildebrandt and Schweinfurth collected during travels in East and in North-East Africa; Hildebrandt’s field trip to Madagascar in 1879-1891 is not included.

<table>
<thead>
<tr>
<th>Region</th>
<th>Collector</th>
<th>Year</th>
<th>No. of collections</th>
<th>Countries</th>
<th>Herbaria where the collectors’ specimens are deposited</th>
</tr>
</thead>
<tbody>
<tr>
<td>North-East Africa</td>
<td>James Bruce</td>
<td>1769-1771</td>
<td>Low</td>
<td>Ethiopia</td>
<td>LINN, P</td>
</tr>
<tr>
<td>East and North-East Africa</td>
<td>J.M. Hildebrandt</td>
<td>1872-1877</td>
<td>1650</td>
<td>Ethiopia, Somalia, Kenya, Tanzania</td>
<td>B [main set, partly lost], BM, BR, CORD, GOET, K [important set], KIEL, L, LY, MO, P, PC, W</td>
</tr>
<tr>
<td></td>
<td>J.H. Speke &amp; J.A. Grant</td>
<td>1860-1863</td>
<td>1650</td>
<td>Tanzania, Uganda</td>
<td>K</td>
</tr>
</tbody>
</table>
more duplicates than the other early collectors, and their collections are represented at more European and North American herbaria than any of the other 19th century collectors (Table 1), thus bringing many plant specimens into herbaria and spreading the knowledge of African plants. Schimper’s and Welwitsch’s collections include significantly more type specimens of African plant species than all other collectors in tropical Africa, both earlier and later (Gillett 1972; Albuquerque et al. 2009). Also a high proportion of Schweinfurth’s collections are types. Friedrich Welwitsch (1806–1872; Fig. 2) carried out expeditions in Angola for over seven years (1853-1860). Two almost equivalent sets of his collections are housed at the Natural History Museum, London, UK (BM) and at the University of Lisbon (LISU), but his duplicates are widespread (Vegter 1988; Albuquerque et al. 2009). Georg Heinrich Wilhelm Schimper (1804-1878; Fig. 3) lived in Ethiopia for more than 40 years, from 1837 to his death (Gräber 1999a, b; Geestrich & McEwan 2015; McEwan 2015). Over the 40 years of his collecting activity, his first set were placed at different herbaria, mainly P and B, where most of it was lost in World War II, but numerous of his duplicates are widely deposited in European and North American herbaria and now partly also in ETH, Addis Ababa (Friis 2007). Georg August Schweinfurth (1836-1925) went to Egypt in 1863, from where he travelled along the Red Sea coast of Africa and through northern Sudan in 1863-1865, including a stay in the border region between Sudan and Ethiopia. Having returned to Europe in 1866, he explored in 1869-1871 the western parts of South Sudan and the north-eastern parts of todays’ Democratic Republic of Congo. From 1874 to 1888 he was based in Cairo and travelled widely in Egypt and to Socotra, and, after his return to Germany, he explored Eritrea in 1891 and 1894 (Wickens 1972).

Later in the 20th century, after European countries had established colonies in Africa, there was an interest to continue the exploration of botanical resources by documenting them in the form of floras and to establish colonial or national herbaria in Africa (Table 2; Fig. 4). The regional survey in Table 2 shows a high

<table>
<thead>
<tr>
<th>Region</th>
<th>Collector</th>
<th>Year</th>
<th>No. of Collections</th>
<th>Countries</th>
<th>Herbaria where the collectors’ specimens are deposited</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Africa</td>
<td>A.M.F.J. Palisot de Beauvois</td>
<td>1786-1788</td>
<td>hundreds</td>
<td>Benin, Nigeria</td>
<td>FI-WEBB, G, GH, P [main set], P-JU</td>
</tr>
<tr>
<td></td>
<td>J. Heudelot</td>
<td>1835-1837</td>
<td>1000</td>
<td>Senegal</td>
<td>A, B, BM, BR, CN, DS, FI, G, K, NY, OXF, P [main set], P-JU, PC, W</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>oon, Bioko, Sao Tomé</td>
<td></td>
</tr>
<tr>
<td>Southern Africa</td>
<td>F.M.J. Welwitsch</td>
<td>1853-1861</td>
<td>3000+</td>
<td>Angola (mainly), Namibia</td>
<td>B, BM [second of two main sets], BOL, BR, C, COI, G, H, K, LE, LISU [first of two main sets ], M, MO, MPU, NU, P, TUR, W</td>
</tr>
<tr>
<td></td>
<td>J. Kirk</td>
<td>1861-1886</td>
<td>2800+</td>
<td>Mozambique, Malawi, Zanzibar</td>
<td>B, CAL, E, F, FHO, GH, K [main set], LE, MO, OXF, W</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
African Collections in Africa and Europe

*Index Herbariorum* (Thiers continuously updated) has recorded 172 herbaria and a total of 7,171,888 collections in sub-Saharan Africa (Table 3). These herbaria are found in 38 out of 49 countries. The establishment of these herbaria, which started in 1864 in South Africa, has continued up to today (Figs. 4), but the size and distribution of these herbaria are extremely variable (Figs. 5, 6). The largest number of specimens are found in herbaria in South Africa (PRE in Pretoria with 1.2 million and NBG Compton Herbarium with just over ½ million) and tropical East Africa (EA in Nairobi with 1 million and SRGH in Harare >½ million; Fig. 6). The herbaria in sub-Saharan Africa have a total of more than 7 million specimens (Table 3). Only Eritrea, South Sudan, Chad, Gambia and Guinea Bissau have no herbaria recorded in the *Index Herbariorum*.

In comparison, the herbarium of the Royal Botanic Gardens, Kew (K), is assumed to have about 2.5 million collections from sub-Saharan Africa out of their total holding of about 7 million. The herbarium of the Museum national d’histoire naturelle at Paris (P) seems to hold slightly more than 700,000 collections from tropical Africa (and slightly more than half a million from Madagascar), to judge from the database [https://science.mnhn.fr/institution/mnhn/collection](https://science.mnhn.fr/institution/mnhn/collection).
Thus, the number of herbarium specimens held in sub-Saharan Africa institutions is significant and, as it would seem, at least as many herbarium collections must be held in herbaria in sub-Saharan Africa as in temperate institutions, which is contrary to the commonly held belief that vastly more African herbarium specimens are deposited in northern institutions than in Africa.

Gaps in Collecting Coverage

The gaps in plant-collecting in sub-Saharan Africa have many causes. During pre-colonial times it was difficult to make collections in most parts of tropical Africa (Fig. 7A). Plant collectors suffered from diseases such as malaria and were hampered by poor infrastructure; Luigi Balugani, the Italian illustrator who accompanied James Bruce, died of dysentery or malaria in Gondar in Ethiopia in 1771 (Hulton et al. 1991), the two French botanical collectors sent on a collecting trip to Ethiopia in 1838 newer returned from their journey, and Richard Quartin-Dillon died in 1840 in northern Ethiopia from an unknown disease. Some
Fig. 6. Size-distribution of herbaria in sub-Saharan Africa and southern Africa. Few herbaria have many specimens, many herbaria have few specimens. Based on information from Thiers (continuously updated).

Table 3. Richness of collections by country in sub-Saharan Africa, based on estimated number of higher plant species, area in km², estimated number of species per 1000 km², number of herbaria, number of collections, collections per 1000 km² and collections per estimated number of species. Data on estimated number of species from Beentje and Smith (2001), with modifications from the checklist of Sudan and South Sudan (Darbyshire et al. 2015), other data from Index Herbariorum (Thiers continuously updated). Countries for which no herbarium has been recorded in the Index Herbariorum are marked with a zero.

<table>
<thead>
<tr>
<th>Country</th>
<th>Estimated number of species</th>
<th>Area (in 1000 km²)</th>
<th>Estimated number of species/1000 km²</th>
<th>Number of herbaria</th>
<th>Number of collections</th>
<th>Collections per 1000 km²</th>
<th>Collections per estimated number of species</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africa</td>
<td>23,400</td>
<td>1223</td>
<td>19.1</td>
<td>55</td>
<td>3,218,590</td>
<td>2631.7</td>
<td>137.5</td>
</tr>
<tr>
<td>Congo (Kinshasa)</td>
<td>10,000</td>
<td>2345</td>
<td>4.3</td>
<td>12</td>
<td>302,894</td>
<td>129.2</td>
<td>30.3</td>
</tr>
<tr>
<td>Tanzania</td>
<td>10,000</td>
<td>940</td>
<td>10.6</td>
<td>6</td>
<td>292,300</td>
<td>311.0</td>
<td>29.2</td>
</tr>
<tr>
<td>Cameroon</td>
<td>8300</td>
<td>475</td>
<td>17.5</td>
<td>5</td>
<td>137,000</td>
<td>288.4</td>
<td>16.5</td>
</tr>
<tr>
<td>Gabon</td>
<td>7200</td>
<td>267</td>
<td>27.0</td>
<td>1</td>
<td>40,000</td>
<td>149.8</td>
<td>5.6</td>
</tr>
<tr>
<td>Ethiopia and Eritrea</td>
<td>6600</td>
<td>1184</td>
<td>5.6</td>
<td>4</td>
<td>137,000</td>
<td>115.7</td>
<td>20.8</td>
</tr>
<tr>
<td>Kenya</td>
<td>6500</td>
<td>583</td>
<td>11.1</td>
<td>3</td>
<td>1,100,000</td>
<td>1886.8</td>
<td>169.2</td>
</tr>
<tr>
<td>Congo (Brazzaville)</td>
<td>6000</td>
<td>267</td>
<td>22.5</td>
<td>1</td>
<td>40,300</td>
<td>150.9</td>
<td>6.7</td>
</tr>
<tr>
<td>Country</td>
<td>Estimated number of species</td>
<td>Area (in 1000 km²)</td>
<td>Estimated number of species/1000 km²</td>
<td>Number of herbaria</td>
<td>Number of collections</td>
<td>Collections per 1000 km²</td>
<td>Collections per estimated number of species</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------------------</td>
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<td>--------------------------------------</td>
<td>--------------------</td>
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<td>--------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Mozambique</td>
<td>5700</td>
<td>783</td>
<td>7.3</td>
<td>5</td>
<td>125,350</td>
<td>160.1</td>
<td>22.0</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>5500</td>
<td>389</td>
<td>14.1</td>
<td>5</td>
<td>540,636</td>
<td>1389.8</td>
<td>98.3</td>
</tr>
<tr>
<td>Uganda</td>
<td>5400</td>
<td>243</td>
<td>22.2</td>
<td>4</td>
<td>84,767</td>
<td>348.8</td>
<td>15.7</td>
</tr>
<tr>
<td>Angola</td>
<td>5200</td>
<td>1247</td>
<td>4.2</td>
<td>4</td>
<td>90,000</td>
<td>72.2</td>
<td>17.3</td>
</tr>
<tr>
<td>Zambia</td>
<td>5000</td>
<td>746</td>
<td>6.7</td>
<td>8</td>
<td>86,000</td>
<td>115.3</td>
<td>17.2</td>
</tr>
<tr>
<td>Nigeria</td>
<td>4700</td>
<td>924</td>
<td>5.1</td>
<td>8</td>
<td>194,500</td>
<td>210.5</td>
<td>41.4</td>
</tr>
<tr>
<td>Côte d'Ivoire</td>
<td>3700</td>
<td>322</td>
<td>11.5</td>
<td>3</td>
<td>40,000</td>
<td>124.2</td>
<td>10.8</td>
</tr>
<tr>
<td>Ghana</td>
<td>3700</td>
<td>238</td>
<td>15.5</td>
<td>5</td>
<td>102,052</td>
<td>428.8</td>
<td>27.6</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>3600</td>
<td>617</td>
<td>5.8</td>
<td>2</td>
<td>10,000</td>
<td>16.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Equatorial Guinea</td>
<td>3300</td>
<td>28</td>
<td>117.9</td>
<td>1</td>
<td>8000</td>
<td>285.7</td>
<td>2.4</td>
</tr>
<tr>
<td>Namibia</td>
<td>3200</td>
<td>824</td>
<td>3.9</td>
<td>1</td>
<td>94,000</td>
<td>114.1</td>
<td>29.4</td>
</tr>
<tr>
<td>South Sudan</td>
<td>3100</td>
<td>620</td>
<td>5.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>?</td>
</tr>
<tr>
<td>Guinea</td>
<td>3000</td>
<td>246</td>
<td>12.2</td>
<td>7</td>
<td>19,800</td>
<td>80.5</td>
<td>6.6</td>
</tr>
<tr>
<td>Somalia</td>
<td>3000</td>
<td>638</td>
<td>4.7</td>
<td>1</td>
<td>10,000</td>
<td>15.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Burundi</td>
<td>2500</td>
<td>28</td>
<td>89.3</td>
<td>1</td>
<td>20,000</td>
<td>714.3</td>
<td>8.0</td>
</tr>
<tr>
<td>Togo</td>
<td>2500</td>
<td>57</td>
<td>43.9</td>
<td>1</td>
<td>21,000</td>
<td>368.4</td>
<td>8.4</td>
</tr>
<tr>
<td>Rwanda</td>
<td>2300</td>
<td>26</td>
<td>88.5</td>
<td>1</td>
<td>16,702</td>
<td>642.4</td>
<td>7.3</td>
</tr>
<tr>
<td>Benin</td>
<td>2200</td>
<td>116</td>
<td>19.0</td>
<td>1</td>
<td>18,000</td>
<td>155.2</td>
<td>8.2</td>
</tr>
<tr>
<td>Liberia</td>
<td>2200</td>
<td>111</td>
<td>19.8</td>
<td>1</td>
<td>7000</td>
<td>63.1</td>
<td>3.2</td>
</tr>
<tr>
<td>Senegal</td>
<td>2100</td>
<td>197</td>
<td>10.7</td>
<td>2</td>
<td>122,000</td>
<td>619.3</td>
<td>58.1</td>
</tr>
<tr>
<td>Sudan</td>
<td>2100</td>
<td>1886</td>
<td>1.1</td>
<td>3</td>
<td>40,500</td>
<td>21.5</td>
<td>19.3</td>
</tr>
<tr>
<td>Swaziland</td>
<td>2100</td>
<td>117</td>
<td>123.5</td>
<td>1</td>
<td>7200</td>
<td>423.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Botswana</td>
<td>2000</td>
<td>30</td>
<td>66.7</td>
<td>5</td>
<td>31,000</td>
<td>1033.3</td>
<td>15.5</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>2000</td>
<td>72</td>
<td>27.8</td>
<td>4</td>
<td>64,857</td>
<td>900.8</td>
<td>32.4</td>
</tr>
<tr>
<td>Chad</td>
<td>1800</td>
<td>1284</td>
<td>1.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Malawi</td>
<td>1800</td>
<td>119</td>
<td>15.1</td>
<td>1</td>
<td>100,000</td>
<td>840.3</td>
<td>55.6</td>
</tr>
<tr>
<td>Mali</td>
<td>1700</td>
<td>1204</td>
<td>1.4</td>
<td>1</td>
<td>6400</td>
<td>53.0</td>
<td>3.8</td>
</tr>
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were even killed by wild animals; Antoine Petit was seized and drowned by a crocodile when crossing the Blue Nile in 1843 (Stearn 1982) and the Italian collector and big-game hunter Emanuele Ruspoli was trampled to death by an angry, wounded elephant near Burgi in Sidamo, southern Ethiopia, in 1893 (Settesoldi et al. 2005).

Even after the colonial period, many problems have persisted in spite of vast improvements in the infrastructure. Gaps in collecting activities persist, as seen in Fig. 7C, because collectors follow the main roads or because access to remote areas remains difficult and dangerous due to political instability. Current areas of instability include those where armed political conflicts are on-going, as widely reported in the international news-media, for example in South Sudan, Eastern Congo and northern Mali. Religious fundamentalism is also seriously destabilizing large areas, such as the activities of Al-Shabab in Somalia, which is making large areas of the neighbouring territories in the Ogaden in Ethiopia and North-Eastern Kenya inaccessible. The activities of Boko Haram impede access to parts of northern Nigeria, and the Lord's Resistance Army has seriously hampered studies in northern Uganda and north-eastern Congo. And also today diseases may make field work difficult or impossible, for example the outbreaks of ebola in Guinean Republic, Liberia and Sierra Leone in 2014–2016.

Conversely, there are areas that are well-collected, and such areas often figure on high-diversity lists, and therefore, they are studied again and again, and their inclusion becomes a self-fulfilling prophesy. But studying lesser-known areas can pay off. For example, Mt Kupe, Mwanenguba and the Bakossi Mountains in Cameroun were virtually unknown (with 123 plant species known from the area in 1993) until a team from Yaoundé and Kew explored them in 1995-2004 and found 2440 plant species, of which 82 were nar-
row endemics, and 232 were threatened taxa (Cheek et al. 2004). These data catapult this area into one of the most important and richest plant diversity spots in tropical Africa, which emphasizes the importance of studying under-explored areas. A similar case is the Makueni area of less than 200 km² of wooded grassland in Kenya, which was virtually botanically unknown until an inventory organized by the National Museums of Kenya showed that it housed 847 species, including 758 vascular plants, 20 bryophytes, and 69 lichenized fungi (Malombe et al. 2015).

It is difficult to state much with certainty about what plants are not known or represented in herbaria, but some attempts have been made in Table 3. First we have tried to look at the number of collections per 1000 km², for which the average is 328. Some countries seem to have a reasonably good coverage of collections per 1000 km², with 3–9 times the average. This relates in particular to South Africa (2632 collections per 1000 km²), Kenya (1887 collections per 1000 km²), Zimbabwe (1390 collections per 1000 km²) and Botswana (1033 collections per 1000 km²). These figures do indeed indicate well stocked herbaria, but it should be noted that South Africa, Zimbabwe and Kenya have old herbaria which have acted as central institutions for what is now several separate countries; the EA herbarium in Nairobi, for example, was for long time a central herbarium for Kenya, Uganda and Tanzania, and received also collection from other neighbouring countries. But the fact that more than 25 countries are below the average would seem to suggest serious gaps.

Also the number of collections per estimated number of species for the countries may indicate serious gaps in collecting in many sub-Saharan African countries. Gabon, a species-rich country that covers biodiversity hotspots (Fig. 8A) has only 5.6 collections per estimated species, which is below the average of 6.4.

Gaps in Collecting Activity and Knowledge about Areas of High Diversity

As it seems to be the case with Gabon, many of the high-diversity areas in sub-Saharan Africa, popularly known as biodiversity hotspots, are under-studied and collections from these areas poorly represented in...
herbaria, African as well as European. This makes it difficult to prioritise these areas with high diversity even though they may be threatened. The original and well-known Myers-Mittermeier hotspots (Myers et al. 2000) were painted with a very broad brush, and the resulting picture was geared towards public relations for the conservation of areas characterized by the presence of particularly spectacular species, often outstanding species of animals, so-called ‘flagship-species.’ We are not denying the need for conservation in many of these areas, but such hotspots as ‘Horn of Africa’ or ‘Madagascar’ are defined too broadly to be informative. Some of the high-diversity areas within these ‘hotspots’ are pretty small and discrete, such as the Nogaaal Valley in Somalia, the Uluguru and Udzungwa Mountains in Tanzania, or the Bakossi Mountains in Cameroon.

Areas with more than 3000 species per 10,000 km² are quite small. The map only shows the diversity on a continental scale, but even these relatively small areas can sometimes, on a finer scale, be broken up into smaller centres of high diversity, for example the Monts de Cristal in Gabon, which was not included in the map of Myers et al. (2000). Because of their small size these areas are particularly important to focus upon for conservation purposes. In 2004 one of us contributed to the redefinition of the African hotspots on a much finer scale and more linked to hard facts than Myers’ areas (Küper et al. 2004) (Fig. 8B). The map also shows where to protect the most species at lowest cost; that often (but not always) means least human impact, so these are not hotspots, which are defined by having lost at least 70% of their primary vegetation (Myers et al. 2000).
When areas with high diversity and high conservation value are under-collected, then these areas represent high-priority gaps that need addressing. Some such areas may be ‘invisible’ both on distribution and diversity maps and in herbaria because of under-collecting, as proven by the Bakossi Mountains in Cameroon and the Makueni wooded grasslands in Kenya. This points to the need for more fieldwork in as many suspected or potential hot-spots as possible. The study of undiscovered hot-spots may also provide taxonomically interesting new species, such as Ancistrocladus tanzaniensis Cheek & Frimodt-Møller, Diospyros uzungwaensis Frimodt-Møller & Ndang, Lijndenia uzungwarum R.D. Stone & Q. Luke, Asplenium uzungwense Beentje, Coleotrype uzungwaensis Faden & Layton, Pauridiantha uzungwaensis Ntore & Dessein, all described, with many others, within the last fifteen years from humid habitats in the Udzungwa Mountains in Tanzania. The Udzungwa Mountains was a poorly known, but in fact a floristically and faunistically very rich part of the Eastern Arc Mountains, which only became well known after the 1990s (Lovett 1993, 1998).

Equally high and hitherto unnoticed diversity might be seen in dry habitats, for example the 137 new species described from Somalia since ca. 1990 (Thulin 2006). Recent examples of undiscovered floristic richness in dry habitats in the Horn of Africa are a range of striking new species in Acanthaceae, Apocynaceae, Euphorbiaceae, Leguminosae and Solanaceae from the Ogaden in eastern Ethiopia and adjacent parts of Somalia (Thulin et al. 2008; Thulin 2008, 2009a,b,c; Thulin & Vollesen 2015), to which has recently been added two extraordinarily tall, woody and large-flowered species of Commicarpus from an arid high-diversity part of south-eastern Ethiopia (Friis et al. 2016) This also points to the need to study potential hot-spots in order to fill taxonomic gaps.

Gaps in Taxonomic Knowledge

While gaps in collecting activity in high diversity areas mean that the herbaria are not representative, the gaps in taxonomic knowledge mean that collections in herbaria are not updated and properly utilised. Gaps in taxonomic knowledge are twofold: gaps in the broader understanding of taxonomy at the level of genera and species, and gaps in the production of floras and lacking flora-coverage (Sebsebe Demissew 2011, 2014; Beentje 2015). Taxon-knowledge gaps in sub-Saharan Africa itself are especially vexing in the larger families: Poaceae, Fabaceae, and Asteraceae. But larger genera also need their own specialists; although not belonging in the previously mentioned mega-diverse families several large genera are understudied in Africa, such as: Cyphostemma (Vitaceae), Euphorbia (Euphorbiaceae), Ipomoea (Convolvulaceae), Polystachya (Orchidaceae), Barleria (Acanthaceae), and Pavetta (Rubiaceae).

Although there are now reasonably good estimates of the size of the floras of nearly all African countries, the actual coverage with published floras for the continent is still full of gaps (Table 4). The total area of sub-Saharan Africa is 24.2 million km² of which 36% are covered by complete floras (Sebsebe Demissew 2011, 2014; Beentje 2015). Another 34% have incomplete floras, ranging from only very partially complete to almost finished. The Flowering Plants of the Sudan (Andrews 1950–1956), now covering both Sudan and South Sudan and encompassing a sizeable part of sub-Saharan Africa north of the Equator, is based on few collections and does not have much in the way of identification keys, but has been supplemented with check-lists (Friis & Vollesen 1998, 2005; Darbyshire et al. 2014). Finally, some countries do not have scientific floras at all: Chad, Central African Republic, Equatorial Guinea and Congo-Brazzaville, and Gambia, Guinea Bissau, Chad and South Sudan do not seem yet to have established a national herbarium, indeed any herbarium in their countries. For a few areas of high plant diversity field guides have been published, or guides dealing with selected taxa; mostly, these overlap with published floras.

All of this shows the continued need for fieldwork and the subsequent storage and treatment of the collected material in herbaria. Our printed floras are based on existing specimens in herbaria, but work in the field may both add new records and new species
Table 4. Coverage of published floras in sub-Saharan Africa. Data updated from a presentation by H. Beentje at the conclusion of the *Flora of Tropical East Africa* project in 2012. The *Flora of Tropical East Africa* is the largest modern tropical flora ever completed. The species in the *Flora of Southern Africa* area are covered by much other information. The recent checklist of Sudan and South Sudan (Darbyshire *et al.* 2015) includes 3969 species.

| Flora of West Tropical Africa (in 2nd ed.) | 100 | 7072 |
| Flora of Tropical East Africa | 100 | 12,104 |
| Flora of Somalia | 100 | 3165 |
| Flora of Ethiopia and Eritrea | 100 | 7,000 |
| Flora Zambesiaca | 90 | 10,000 |
| Flore de l’Afrique Centrale | 60 | 10,000 |
| Flore du Cameroun | 40 | 9,000 |
| Flore du Gabon | 40 | 7,000 |
| Flore de Madagascar | 35 | 12,000 |
| Flora of Southern Africa | 13 | 23,400 |

(Friis 2014); and, moreover, add information useful in making conservation assessments, such as population sizes and threat levels.

**Gaps in Resources and Taxonomic Impediment**

The taxonomic impediment, which is caused by shortage of herbarium material and taxonomic information, of floristic coverage, and of taxonomic practitioners, is often the main reason for big gaps. Quite frequently the reasons for gaps are financial – fieldwork the establishment and maintenance of herbaria and the employment of herbarium scientists and curatorial staff comes pretty low on most governments’ and institutions’ priority lists. As a result there is a world-wide shortage of vital taxonomic information to manage/conserve/use our biodiversity. The importance of the taxonomic impediment was recognized by the Convention on Biological Diversity (CBD), signed at the 1992 Rio Earth Summit, but the initiatives taken have not yet solved the problem. The number of practicing taxonomists has been shrinking for several decades, and many taxonomists are now quite advanced in years or practicing in their retirement (Ingrouville 1989; Buyck 1999; Drew 2011).

An important reason for the underfunding of taxonomy is that the discipline is looked upon as old-fashioned, stagnant and not producing economically important results. Far too often it is taken for granted that plants are easy to name, which in very many cases they are not. Increasing funding can only come out of more general awareness of how vital a function taxonomists fulfil. More appreciation of what we do is needed, and it has to be made clear that taxonomists provide vital baseline data utilised by a host of other researchers, from scientists involved in DNA-barcoding and -phylogeny to biochemists,
pharmacologists, conservationists, ecologists, ethnographers and even forensic scientists in the service of the police, at times.

There is also an access problem: much of the information provided by taxonomists is locked up in herbaria only accessible to scientists, in obscure publications, or in peoples’ heads. The production of floras is one way to synthesize such data. But to improve and streamline the accessibility of our scientific results we need more training, more staff, and this equates to more money. It is vital that a new generation can take over, using modern methods in communication to (maybe) speed up the completion of floras and the popularization of the importance of wild plants. In the meantime, we can work on making our data more easily accessible, in more user-friendly formats as e-floras, overview databases and field guides.

Positive Development

Taxonomists are slowly closing some of the gaps mentioned above. We are still collecting, at least in certain parts of Africa, naming the collections and incorporating them in herbaria, we are tackling large genera and problem groups, through collaboration and through using both classical and modern methods. We are making our data more accessible by publishing on the web as well as in hardcopy, by making databases available, by sharing and by teaching.

Collections, revisions and monographs are what powers taxonomic progress. They build on fieldwork, herbarium studies and accumulated expertise, and solve problems of taxonomic interrelationships; they provide the floras with the hard-core science on which to build floras, field guides, ecological studies, etc. Floras synthesize all existing knowledge and make it accessible in a unified format. Formats of printed floras themselves may vary quite a bit, but they should ideally all provide solid contributions to our understanding of the African plant world, an understanding on which future generations can build. And some flora projects are also excellent capacity-building taxonomic projects, based on close collaboration between taxonomists in the South and in the North: a shining example is the Flora of Ethiopia and Eritrea (Hedberg 2011; Sebsebe Demissew 2011, 2014). Once a flora for a country or a region has been completed, it may give rise to spinoff products like field guides, which are both more restricted in scope than the original flora and more user-friendly. There is also the important category of overview websites that build on floras and monographs. One can mention the International Plant Names Index (IPNI), a database of plant names and associated basic bibliographic information (www.ipni.org), TROPICOS, with information on 4.3 million specimens, many of which are from Africa, and bibliographic data (www.tropicos.org); the Biodiversity Heritage Library (BHL), through which much taxonomic literature is made available on-line (www.biodiversity-heritagelibrary.com), JSTOR, with on-line access to historical journals (www.jstor.org) and the Global Plants Initiative (GPI), Global Plants on JSTOR, with scanned high-resolution images of more than two million type specimens (plants.jstor.org).

A number of partially linked and unique resources for plant taxonomists and other interested users deal especially with the plants of sub-Saharan Africa: (1) a number of volumes in two series, entitled Énumération des plantes à fleurs d’Afrique tropicale and Tropical African Flowering Plants by Lebrun and Stork (1991–1997; 2003–2015). The two series list all the species of vascular plants occurring in tropical Africa, the later series with ecological information and generalized distribution maps. (2) The extremely accessible and useful African Plant Database (http://wwwville-ge.ch/musinfo/bd/cjb/africa/recherche.php) in which one can search for any African plant name (199,873 in total in May, 2017) and find bibliographical data, synonymy, notes on ecology and distribution, a generalized map, and links to other sites such as (Global Plants on JSTOR). (3) Photo guides with images of many species, such as http://www.africanplants.senckenberg.de/root/index.php. All these aid both herbarium curation and taxonomic research in sub-Saharan Africa.
Conclusions

We have seen that plant collections in sub-Saharan Africa are more and more kept in Africa itself, and the collections are spread widely over the continent. These plant collections do not cover all areas equally, and collecting gaps remain in high diversity hotspots, as seen from a comparison of Table 3 with Fig. 9. The hotspots should be investigated before it is too late, but it is important to remember that not all high diversity areas have been localised or can be predicted.

The taxonomic impediment is strong in Africa, mainly due to underfunding. This causes a shortage of trained taxonomists and curators. We need to address this, as a community, by making it clear that we fulfil a vital role, on which many other disciplines rely. In the post-colonial time and until the present, collaboration between taxonomists in the South and in the North has been very productive (Beentje 2015; Hedberg 2011; Sebsebe Demissew 2011, 2014; Onana 2017), resulting in national or regional floras of high standards. The number of taxonomists in the North who can take part in future collaborative efforts is declining, adding to the taxonomic impediment in the South. African taxonomists cannot change this development in Europe and North America, but one can hope that increasing South-South collaboration, and the increasing ability of African botanists to attract their own funding, might alleviate some of this impediment in the future.

As shown in this paper, many of the areas of high plant diversity in tropical Africa remain under-collected and under-studied. Where such areas are rich in species and coincide with threats to the habitats, they should become priority areas for collecting and study, in order to give a strong basis for coming conservation proposals.

There is a current need in many countries in sub-Saharan Africa to complete their national botanical inventories for conservation purposes, for sustainable use of their plant resources, and to fulfil their obligations to the Aichi Biodiversity Targets (https://www.cbd.int/sp/targets/) by 2020. This will require more alpha level taxonomic research to in under-explored areas in sub-Saharan Africa, despite the progress made in specimen collections, flora documentation, and in the fields of molecular systematics.

While large gaps remain in flora coverage, we urgently need more specialists in large families, both for the curation of herbaria and for the many practical uses of taxonomic treatments. There is good progress in making our work more accessible, and therefore in collaboration between colleagues, both inside the discipline and with colleagues in other fields. Much remains to be done, both with the plant collections of Africa and with their utilisation, and continuing threats to the biodiversity all over the continent make this urgent — but there is hope for the future, too, with much already accomplished.

References


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