

# Tropical African floras: progress, gaps, and future

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Coverage of African floras is uneven: for 36% of the land area of sub-Saharan Africa, completed floras exist, but for another 38% floras remain incomplete (with completeness varying from 5-90%). For another 10% the coverage is either completely out of date and based on very few collections, or in the form of a checklist; and for the final 16% there is no flora at all. The coverage is discussed on a country-by-country basis, with notes on the density of plant collecting, and includes recent initiatives. The uses of floras in general, and in making RedList conservation assessments specifically, are discussed.

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## Introduction

Sub-Saharan Africa covers an area of 24.2 million km<sup>2</sup>, with an estimated 46,500 plant species (Klopper et al. 2006). Our knowledge of these plant species is uneven: the correct names to give them, the relationships between them, and the way to identify them. Such knowledge is provided by *floras*: large-scale publications dealing with all the plants of a region or large country. Floras are usually produced by a large-scale institution such as a major herbarium, or by a consortium of institutions; such floras need large numbers of specialists to work on them, which means international collaboration, as well as people with long-term vision and determination to run them. For some African countries good floras exist, with keys, descriptions, synonymy, notes on habitat and distribution, and illustrations. Such countries have a solid knowledge base to work from, on any subject requiring information on wild plant species; and that includes RedList assessments, which in turn

leads to a solid basis in conservation work. Other African countries have neither floras nor checklists, which makes any work on wild plant species very difficult indeed. Most countries in Africa come somewhere in between these two extremes, with either partially complete floras, or only checklists of species but no complete overview.

Information on coverage of regional and national floras in Africa was given by Frodin (1984, 2001), and here I try to update those useful works for tropical Africa. In the following article I will try to give an overview of the status quo of our knowledge of wild plant species, on a country-by-country basis.

The differences between a good flora and a checklist are enormous, but that does not mean that checklists are not important. For those countries where no floras exist, or they are incomplete, a national checklist is the essential starting point for further work. Of course, partial checklists (say, for a large national park, a mountain range, or part of the country) may

exist, and provide useful knowledge; but here I deal only with national and regional floras and checklists. What I also mention are field guides that deal with specific large groups of taxa: the woody plants of a country, or (in cases where floras are very incomplete) fieldguides to the plants of large parts of the country.

### The main regional Floras

These floras are the backbone of African plant taxonomy – national floras depend on them and build on them, fieldguides come out when the regional floras are complete, and they show up the gaps in our knowledge – gaps in collecting density, and gaps in our taxonomic knowledge. They do take a long time to complete, though. The first of them all, the *Flora of Tropical Africa*, took from 1868 to 1937, and was based on very few specimens per species. Later floras built on this foundation, but sometimes took almost as long: the *Flore d'Afrique Centrale* has been going for 67 years, and *Flora Zambesiaca* (FZ) for 55 years; and neither of them is complete, as yet. The *Flora of Tropical East Africa* (FTEA) is complete, but took 61 years to reach this stage. Quicker floras have been the *Flora of West Tropical Africa* (FWTA) (2nd edition complete in 15 years) and the *Flora of Ethiopia and Eritrea* (complete in 20 years). And when I say 'complete in so many years' I do not count the lead-in time for starting up the project. Large regional floras resemble a process more than a project, at times, and can only be run from major institutes with a long-term vision.

A perennial problem is how to cite these long-running serial floras. We regularly see FTEA referred to as "Turrill & Milne-Redhead (eds) *Flora of Tropical East Africa*" while this combination of editors lasted only six years, out of the total sixty-one years it took to complete this flora! The changing of editors in long running floras is common; but in some other floras the situation is even worse, as editors do not get a mention at all. Sometimes the place, or institute, of publication changes over the years; or the name of the whole flora changes in mid-stream.

A list of the serial regional African Floras follows, with some of the main changes listed. Individual parts of a Flora are of course best cited under the individual author, such as "Verdcourt B. 1992. *Verbenaceae*. In *Flora of Tropical East Africa*. Balkema, Rotterdam." Please note that I do not include the *Flora of Tropical Africa* (1868–1937) in this overview, as I consider this too out of date; even though for some countries it forms the only coverage of their wild plant species. Single country Floras appear in the next section, National Floras.

Most of the following regional floras are large-scale descriptive research floras, with keys to genera and species, regional synonymy with references, literature references, full descriptions, data on habitat and distribution (including overall range), specimen citations, indices, illustrations and glossaries; only FWTA differs in having very short descriptions and not much information on habitat. FTEA and FZ appeared in Rudi Schmid's overview of floras (Schmid 1997), and received his qualifications of 'certainly very good' and 'world class', respectively.

### Flora of Ethiopia / Ethiopia and Eritrea

Abbreviated below as **FEE**. Covering Ethiopia and Eritrea; complete and up to date. The first part that appeared (volume 3) bore the title *Flora of Ethiopia*; after this all volumes are called *Flora of Ethiopia and Eritrea*. Within the volumes blocks of related families are treated according to the Hutchinson sequence; the volumes were published when ready, so are not in numerical sequence.

- Hedberg, I. & Edwards, S. (eds) 1990 ("1989"). Vol. 3. Addis Ababa, Asmara & Uppsala.
- Edwards, S., Mesfin T. & Hedberg, I. (eds) 1995. Vol. 2 (2). Addis Ababa & Uppsala.
- Hedberg, I. & Edwards, S. (eds) 1995. Vol. 7. Addis Ababa & Uppsala.
- Edwards, S., Sebsebe D. & Hedberg, I. (eds) 1997. Vol. 6. Addis Ababa & Uppsala.
- Edwards S., Mesfin Tadesse, Sebsebe Demissev & Hedberg, I. (eds) 2000. Vol. 2 (1). Addis Ababa & Uppsala.

Hedberg, I., Edwards, S. & Sileshi N. (eds) 2003. Vol. 4 (1). Addis Ababa & Uppsala.

Hedberg, I., Friis, I. & Edwards, S. (eds) 2004. Vol. 4 (2). Addis Ababa & Uppsala.

Hedberg, I., Ensermu K., Edwards, S., Sebsebe D. & Persson, E. (eds) 2006. Vol. 5. Addis Ababa & Uppsala.

Hedberg I., Friis, I. & Persson, E. (eds) 2009. Vol. 1. Addis Ababa & Uppsala.

Hedberg I., Friis, I. & Persson, E. (eds) 2009. Vol. 8, General Part and Complete Index. Addis Ababa & Uppsala.

### **Flora of Southern Africa**

Abbreviated below as **FSA**. Covering Namibia, Botswana, South Africa, Lesotho and Swaziland; less than 20% complete (my estimate). Appeared in numbered parts (numbered according to a modified Engler sequence), with vol. 26 appearing first:

Dyer, R.A., Codd, L.E. & Rycroft, H.B. (eds) 1963. Flora of Southern Africa, Vol. 26. South African Government Printer, Pretoria.

Fascicles were published when ready, so not in numerical sequence, with the most recent part number 33.4.1 (edited by Germishuizen, G. & du Plessis, E.) appearing in 2001.

### **Flora of Tropical East Africa**

Abbreviated below as **FTEA**. Covering Uganda, Kenya and Tanzania; complete, but the earlier parts often need to be revised. Appeared in 255 fascicles of families or part of families, so not according to any system; the parts are not numbered.

1952–1958: 20 fascicles. Turrill, W.B. & Milne-Redhead, C.E. (eds). Crown Agents, London.

1958–1966: 23 fascicles. Hubbard, C.E. & Milne-Redhead, E. (eds). Crown Agents, London.

1966–1972: 40 fascicles. Milne-Redhead, E. & Polhill, R.M. (eds). Crown Agents, London.

1973–1978: 23 fascicles. Polhill, R.M. (ed.). Crown Agents, London.

1982–1997: 76 fascicles. Polhill, R.M. (ed.). Balkema, Rotterdam.

1998–2002: 40 fascicles. Beentje, H.J. (ed.). Balkema, Rotterdam.

2003: 6 fascicles. Beentje, H.J. & Ghanzanfar, S. (eds). Balkema, Rotterdam.

2005–2009: 32 fascicles. Beentje, H.J. & Ghanzanfar, S. (eds). Royal Botanic Gardens, Kew.

2010–2012: 5 fascicles. Beentje, H.J. (ed.). Royal Botanic Gardens, Kew.

### **Flora of West Tropical Africa**

2nd edition (the first was completed in 1936). Abbreviated below as **FWTA**. Roughly covering Upper Guinea: southern Mauritania, Senegal, Gambia, Guinea Bissau, Guinée, Sierra Leone, Liberia, most of Mali, Burkina Faso, Cote d'Ivoire, Ghana, Togo, Benin, the southern half of Niger, Nigeria, the Western part of Cameroun and Bioko; complete, but needs revision. The sequence is according to Hutchinson. Keys are present, as are illustrations and the citation of voucher specimens, but descriptions and habitat data are kept very short.

Hutchinson J. & Dalziel J.M., revised by Keay, R.W.J. 1954. Vol. I (1). Crown Agents, London.

Hutchinson J. & Dalziel J.M., revised by Keay, R.W.J. 1958. Vol. I (2). Crown Agents, London.

Hepper, F.N. (ed.) 1963. Vol II. Crown Agents, London.

Hepper, F.N. (ed.) 1968. Vol. III. Crown Agents, London.

### **Flora Zambesiaca**

Abbreviated below as **FZ**. Covering Malawi, Zambia, Mozambique, Zimbabwe and Botswana, as well as the Caprivi Strip of Namibia; 88% complete (Timberlake, pers. comm.), with earlier parts often in need of revision. Appearing in volumes of blocks of related families, arranged according to a slightly modified Bentham & Hooker sequence; published when ready, volume numbers not chronological.

Exell, A.W. & Wild, H. (eds) 1960–1961. Vol. 1. Crown Agents, London.

Exell, A.W., Fernandes, A. & Wild H. (eds) 1963–1966. Vol. 2. Crown Agents, London.

Brenan, J.P.M. (ed.) 1970. Vol. 3.1. Crown Agents, London.

- Exell, A.W. & Launert, E. (eds) 1970. Pteridophyta. Crown Agents, London.
- Fernandes, A., Launert, E. & Wild, H. (eds) 1971. Vol. 10.1. Flora Zambesiaca Managing Committee.
- Launert, E. (ed.) 1978–1989. Vol. 4 (1978), 7.2 (1985), 8.1 (1987), 8.3 (1988), 9.1 (1988), 5.1 (1989). Flora Zambesiaca Managing Committee.
- Launert, E. & Pope, G.V. (eds) 1989–1991. Vol. 10.3 (1989), 7.4 (1990), 8.2 (1990), 9.6 (1991). Flora Zambesiaca Managing Committee.
- Pope, G.V. (ed.) 1992–2001. Vol. 6.1 (1992), 12.4 (1993), 11.1 (1995). Flora Zambesiaca Managing Committee.
- Pope, G.V. (ed.) 1996–2001. Vol. 9.4 (1996), 9.2 (1997), 5.2 (1998), 11.2 (1998), 10.2 (1999), 3.6 (2000), 3.5 (2001). Royal Botanic Gardens, Kew.
- Pope, G.V. & Martins, E.S. (eds) 2002–2005. Vols. 10.4 (2002), 5.3 (2003) [Pope alone], 3.7 (2003) [co-ed with R.M. Polhill], 8.4 (2005), 8.7 (2005). Royal Botanic Gardens, Kew.
- Pope, G.V., Polhill, R.M. & Martins, E.S. (eds) 2006. Vol. 9.3 (2006). Royal Botanic Gardens, Kew.
- Timberlake, J.R., Pope, G.V., Polhill, R.M. & Martins, E.M. (eds) 2007. Vol. 3.2 (2007). Royal Botanic Gardens, Kew.
- Timberlake, J.R., Polhill, R.M., Pope, G.V. & Martins, E.M. (eds) 2007. Vol. 3.3 (2007). Royal Botanic Gardens, Kew.
- Timberlake, J.R. & Martins, E.M. (eds) 2008–2015. Vols. 13.1 (2008), 12.2 (2009), 13.2 (2010), 13.4 (2010), 12.1 (2012), 3.4 (2012), 8.8 (2013), 8.5 (2013), 8.6 (2015). Royal Botanic Gardens Kew.

**Flore du Congo Belge et du Ruanda-Urundi**, later continued as **Flore d’Afrique Centrale**.

Abbreviated below as FCB and FAC. Covering Congo (Kinshasa), Rwanda and Burundi; about 2/3 complete (my estimate); many parts need revising. Appearing in fascicles of families (and then in a modified Engler sequence) or part of families; published when ready, not numbered.

[editors not indicated] 1948–1963. Flore du Congo Belge et du Ruanda-Urundi. Vol. 1 (1948) – 10 (1963). INEAC, Bruxelles.

After 1967 published in separate fascicles, one per family or part of family, published when ready.

Bamps, P. (ed.) 1972–. Jardin Botanique National de Belgique, Bruxelles.

The flora was dormant from the mid-1990s onwards, but has been revived recently, as ‘nouvelle série’. Eight parts have been published in 2014 and 2015, with several more being edited.

Sosef, M.S.M. (ed.) 2014–. Jardin Botanique, Meise.

**National Floras**

In this section I deal with the sub-Saharan countries on a country basis, giving the estimated number of plant species (ferns, gymnosperms and angiosperms, unless indicated otherwise; estimates of species numbers based on Beentje et al. 1994, unless indicated otherwise), listing flora coverage and other important plant overview literature.

*Notes:* a “full flora” means the flora has descriptions, synonymy, notes on distribution and habitat, and some images; a “partial flora” means just that, with notes on what is there and what is not; an “annotated checklist” means there are some data about life-form, synonymy and ecology.

**ANGOLA**

6961 species (Figueiredo & Smith 2008). Partly well-collected, partly under-collected.

*Conspectus Flora Angolensis* (IICT, Lisboa) is only a partial flora (in Portuguese) – there are keys, but no descriptions; it does give good literature citations, synonymy, specimen citation, and notes on habitat / ecology, distribution, taxonomy. Coverage is low: I estimate less than 33% published, and only four thin parts have appeared since 1977. As the first parts were published in 1937, much of it is considerably out of date. Blocks of related, numbered families are treated within the volumes. Editorial / publication sequence:

- Exell, A.W. & Mendonça, F.A. (eds) 1937. Vol. 1 (1). Junta de Investigações Coloniais, Lisboa.
- Exell, A.W. & Mendonça, F.A. (eds) 1951. Vol. 1 (2). Junta de Investigações Coloniais, Lisboa.

Exell, A.W. & Mendonça, F.A. (eds) 1954. Vol. 2 (1). Junta de Investigações do Ultramar, Lisboa.

Exell, A.W. & Mendonça, F.A. (eds) 1956. Vol. 2 (2). Junta de Investigações do Ultramar, Lisboa.

Exell, A.W. & Fernandes, A. (eds) 1962. Vol. 3 (1). Junta de Investigações do Ultramar, Lisboa.

Exell, A.W. & Fernandes, A. (eds) 1966. Vol. 3 (2). Junta de Investigações do Ultramar, Lisboa.

Exell, A.W., Fernandes, A. & Mendes, E.J. (eds) 1970. Vol. 4. Junta de Investigações do Ultramar e Instituto de Investigação Científica de Angola, Lisboa.

After 1970 CFA has appeared as fascicles, each dealing with a family or (in Pteridophyta) group of related families:

Fernandes, R.B., Launert, E. & Mendes, E.J. (eds) 1977. fasc. Pteridophyta.

Fernandes, E.J. & Mendes, E.J. (eds) 1982. fasc. 70. Instituto de Investigação Científica Tropical, Lisboa.

Paiva, J. et al. (eds) 1993. fasc. 122. Instituto de Investigação Científica Tropical, Lisboa.

A recent initiative by Gideon Smith and Estrela Figueiredo has been the Flora Angola Online, see <http://floras.cenapad.unicamp.br/floradeangola>, which has covered all families in a preliminary manner – a solid start, but not a real Flora yet.

A checklist (Figueiredo & Smith 2008) gives the synonymy as well, plus distribution data within Angola and voucher specimens.

## **BENIN**

2807 species (Akoègninou et al. 2006). Well-collected in most parts.

*Flore du Benin* (Akoègninou et al. 2006) is a full flora (in French), giving keys, short descriptions, bibliography, distribution data, specimen citation, habitat data, local names and uses, with some taxa illustrated. The sequence is systematic.

Benin is also treated as one of the countries covered by the FWTA.

## **BOTSWANA**

3041 species (Setshogo 2005). Well-collected in most parts?

Treated as one of the countries covered by the FZ.

Setshogo (2005) is a checklist with synonymy.

A field guide to the plants of northern Botswana (Heath & Heath 2009, in English) treats 530 species, arrangement based on flower colour, many photos.

## **BURKINA FASO**

2067 species (Thiombiano et al. 2011). Moderately well-collected.

Treated as one of the countries covered by the FWTA.

An annotated checklist (in French) was published by Thiombiano et al. (2011) and includes synonymy, literature references, local names and uses, habitat, distribution and specimen citations.

A field guide to the trees (Sacande et al. 2012, in French) deals with 226 species, has keys, distribution maps, local names and uses, habitat, distribution, conservation listings, seed data and many photos.

## **BURUNDI**

About 2500 species. Well-collected.

Treated as one of the countries covered by the FAC (which is as yet incomplete).

## **CABO VERDE**

651 species (Sunding 1973). Collection coverage unknown to me.

*Flora de Cabo Verde* (IICT, Lisboa, in Portuguese), with 106 parts appeared up to 2002 (which is the most recent one in the Kew library) (<http://memoria-africa.ua.pt/Library/FCV.aspx>) — all looking thin. About half complete? The parts that have appeared show this is a flora with keys / bibliography / full descriptions / distribution / specimen citation / habitat / local names and uses.

## **CAMEROUN / CAMEROON**

About 8300 species. Collecting coverage varies considerably.

*Flore du Cameroun* (in French), a flora with keys / bibliography / synonymy / full descriptions / types / habitat / local names / specimen citations. Appearing in fascicles of families or groups of related families, published when ready, numbered chronologically.

Fascicles 1–20; 1963–1974. Muséum National d'Histoire Naturelle, Paris.

Fascicles 21–; 1981–. D.G.R.S.T., Cameroun.

Editors not indicated in the first volumes; according to small print in the endpapers: Raynal, J. for fascicles 5–10, Letouzey, R. for fascicles 11–12, Cusset, C. for fascicles 13–33.

The western part of the country (formerly a British mandate, about 10%) is treated within the FWTa.

Onana (2011) gives a full checklist of Cameroun species.

A series of conservation checklists has been published for high-diversity areas of the country (Cable & Cheek 1998; Cheek et al. 2000; Cheek et al. 2004; Cheek et al. 2010; Cheek et al. 2011; Harvey et al. 2004; Harvey et al. 2010).

#### **CENTRAL AFRICAN REPUBLIC / REPUBLIQUE CENTRAFRICAINE**

About 3600 species (Lebrun & Stork 1991). Many parts under-collected.

Not covered by any flora treatment or checklist.

522 species from the border area of Cameroun, CAR and Congo, with keys and short descriptions are treated in Harris & Wortley (2008).

#### **CHAD / TCHAD**

2256 species (Brundu & Camarda 2013).

1450 species for the S half (Lebrun et al. 1972). Under-collected.

Not treated in any existing flora.

An annotated checklist for the part of the country south of 16° N (about half) is given by Lebrun et al. (1972). A checklist for the whole country (in English) is Brundu & Camarda (2013), which gives synonymy as well.

#### **CONGO (Brazzaville)**

4397 species (Sita & Moutsambote 1988) but possibly as many as 6000 species (Morat & Lowry 1997). Under-collected in most parts.

Not covered by any flora treatment.

A straightforward checklist of taxa is Sita & Moutsambote (1988), which states that the country is still very under-collected in large parts, especially the north.

#### **CONGO (Kinshasa, DRC)**

About 10,000 species. Some parts well-collected, some parts under-collected.

Treated as one of the countries covered by the FAC (which is as yet incomplete).

#### **COTE D'IVOIRE / IVORY COAST**

3853 species (Aké Assi 2002). Mostly well-collected.

Treated as one of the countries covered by the FWTa.

Checklist given by Aké Assi (2001, 2002) who also gives some notes on ecology of the taxa.

#### **DJIBOUTI**

783 species (Audru et al. 1994). Mostly well-collected.

A Flora (Audru et al. 1994) in French has keys, synonymy, very short descriptions, habitat notes; most species are illustrated. The sequence is systematic.

A slightly earlier checklist (Lebrun et al. 1989) lists 641 species, but does not include the introduced species that the Flora has; the checklist has main literature, synonymy, specimen citations, notes on habitat and distribution.

#### **ERITREA**

2152 species (Ensermu & Sebsebe 2014). Mostly well-collected, but some parts under-collected.

Treated in the FEE.

## **ETHIOPIA**

5757 species (Ensermu & Sebsebe 2014). Mostly well-collected, but some parts under-collected.

Treated in the FEE.

A guide to the plants of the Simen Mts (Puff & Sileshi 2005) treats 545 species, all illustrated.

## **GABON**

Possibly 5000+ species. Collecting intensity varies over the country.

*Flore du Gabon* (in French) has keys, bibliography, synonymy, full descriptions, distribution, habitat, local names and specimen citations; illustrated for some species.

1961– . Fascicles 1–; Muséum National d’Histoire Naturelle, Paris.

Appearing in fascicles of families or groups of related families, published when ready, numbered chronologically. Editors not indicated up to fascicle 19, then in small print on the endpapers for fascicles 20–31, hereafter not indicated.

An annotated checklist (Sosef et al. 2006) lists 4710 species, but states that the country is still poorly known botanically; it estimates the total number of species might be as high as 7000.

## **GAMBIA**

About 1000 species. Well-collected.

Treated as one of the countries covered by the FWTA.

A checklist is given by Jarvis (1980).

## **GHANA**

About 3700 species. Well-collected.

Treated as one of the countries covered by the FWTA.

Woody plants are dealt with by Irvine (1961) and Hawthorne (1990), both in English and dealing with 200+ species.

## **GUINEA-BISSAU**

About 1400 species. Moderately well-collected.

*Flora da Guinea-Bissau*, ten parts appeared between 1970–1983 (in Portuguese); completion of the flora about 5%. This flora has bibliography, synonymy, full descriptions, specimen citations, habitat and distribution data; no illustrations.

Treated as one of the countries covered by the FWTA.

An annotated checklist was published in Portuguese (Catarino et al. 2006) and English (Catarino et al. 2008), with life form, habitat, phenology, national distribution and some local names; it does not mention the total number of species listed.

## **GUINEA EQUATORIAL / EQUATORIAL GUINEA**

About 3300 species. Under-collected.

This country encompasses the continental territory of Rio Muni as well as the islands of Bioko and Annobon.

*Flora de Guinea Ecuatorial* is represented by three published volumes (ferns, legumes, and some monocot families); it is in Spanish, and has the descriptions folded into the identification keys, with bibliography, habitat, distribution data, specimen citations; it has distribution maps and specimen scans.

## **GUINÉE**

2923 species (excluding ferns and gymnosperms; Lisowski 2009). Many parts of the country are under-collected.

Recent and in-depth treatment in the *Flore du Guinée* (Lisowski 2009), in French: synonymy, descriptions, habitat, distribution and specimen citation.

Treated as one of the countries covered by the FWTA.

## **KENYA**

6596 species (Q. Luke, pers. comm. Sept. 2015). Well-collected.

Treated as one of the countries covered by the FTEA.

Woody plants are treated in Beentje (1994) — about 1800 species; herbs and ferns of about a quarter of the country are treated in Agnew (2013) with 3600 species, of which one third are illustrated. Interesting field guides include Dalitz et al. (2011) on the plants of Kakamega forest with 288 species, all illustrated.

### LESOTHO

1537 species (Guillarmod 1971). Under-collected?

The *Flora of Lesotho* (Guillarmod 1971) is in English and is really more of a checklist than a flora: there are no keys or descriptions, but it lists the taxa with specimen citations, distribution and habitat; a separate section has local names; there are no illustrations.

### LIBERIA

About 2200 species. Moderately well-collected. Treated as one of the countries covered by the FWTA.

### MALAWI

About 3800 species. Mostly well-collected.

One of the countries covered by the FZ.

The woody species are covered in White et al. (2001), which treats 712 species.

The Nyika, an area of high plant diversity, is covered in Burrows & Willis (2005), who list 1817 species and give short descriptions, habitat, distribution, some literature, specimen citations (but no keys) and many illustrations.

### MALI

1739 species (Boudet & Lebrun 1986). Collecting density varies over the country.

The southern two-thirds of the country is covered by FWTA, which probably accounts for over 90% of the species of the country, the rest being virtually all Sahara desert — though this includes the massif of the Adrar des Ifhogas.

Boudet G. & Lebrun J.-P. (1986) is an annotated checklist.

A field guide to the trees is in press (Sacande, Sanogo & Beentje 2016).

### MAURETANIA

About 1700 species. Not very well collected.

*Flore de Mauritanie* (Barry & Celles 1991?): in French, this publication has species descriptions folded within the identification keys, and many illustrations; the authors state the knowledge of plants of the country is still imperfect; they do not give a total number of species included. The sequence is systematic.

The southern part of the country is covered by FWTA, which probably accounts for over 75% of the species of the country, the rest being virtually all Sahara desert.

### MOZAMBIQUE

3932 species (Calane et al. 2004) but might be as high as 6000 (Beentje 1994). Moderately well-collected.

The country is covered by FZ.

*Flora de Mocambique* (IICT, Lisboa, in Portuguese) is a flora derived from FZ, but I estimate that coverage is less than 40% published, so far. See [http://www2.iict.pt/archive/doc/Flora\\_de\\_Mo\\_ambique-final.pdf](http://www2.iict.pt/archive/doc/Flora_de_Mo_ambique-final.pdf); not much has come out since 1981. There are keys, literature, synonymy, full descriptions, specimen citations, habitat and distribution. This flora appears in fascicles of families, published when ready, numbered in systematic sequence.

Editorial citation:

Fernandes A. (ed.) 1973. Junta de Investigações do Ultramar, Lisboa.

Mendes E.J. (ed.) 1979–1982. Junta de Investigações do Ultramar, Lisboa.

Mendes E.J. (ed.) 1983–1986. Instituto de Investigação Científica Tropical, Lisboa.

(no editor given). 1990–1993 Instituto de Investigação Científica Tropical, Lisboa.

A hopeful online project is <http://www.mozambiqueflora.com/> mostly consisting of links to other existing sites.



A checklist (in English) is given by Calane et al. (2004) and lists 3932 taxa, with synonymy and some local names.

#### **NAMIBIA**

3961 species excluding ferns (Craven 1999). Well-collected, but some high-diversity areas still undercollected?

The country is treated in FSA, still incomplete. The Caprivi Strip is covered by the FZ.

The *Prodromus* (Merxmüller 1966–1970, in German) covers most species, and has keys, literature, synonymy, specimen citations, national distribution, but no descriptions (apart from what is mentioned in the keys), no habitat notes, no illustrations. This flora appeared in fascicles of families or groups of related families, published when ready. A final volume with keys to families and index appeared in 1972, plus an ‘additions’ volume in 1976 (Roessler & Merxmüller 1976).

Craven (1999) gives a checklist with synonymy.

There are several excellent field guides, as well as a Tree Atlas (Curtis & Mannheimer 2005) with over 400 species.

#### **NIGER**

1045 species (Peyre de Fabregues & Lebrun 1976). Moderately well to under-collected.

The southern two-thirds of the country is covered by FWTA, which probably accounts for over 90% of the species of the country, the rest being virtually all Sahara desert.

An annotated checklist is Peyre de Fabregues & Lebrun (1976), in French; it gives literature, synonymy, specimen citations, habitat, distribution and uses.

#### **NIGERIA**

About 4700 species. Collecting intensity varies, with especially the south-east undercollected.

Treated as one of the countries covered by the FWTA.

A planned *Flora of Nigeria* (Stanfield & Lowe 1970–1989) did not progress beyond 3 fascicles.

The trees of Nigeria are treated by Keay (1989), with 935 species represented.

#### **RWANDA**

About 2300 species. Well-collected.

*Flore du Rwanda* (Troupin 1978, 1983, 1985, 1988) is in French and has keys, local names, short descriptions, habitat, distribution, specimen citations and many illustrations. The sequence is systematic.

Treated as one of the countries covered by the FAC, as yet incomplete.

Woody plants are treated in Bloesch et al. (2009), dealing with 540 species.

The field guide to the plants of Nyungwe National Park (Fischer & Killmann 2008) deals with 650 species, all illustrated.

#### **SAO TOME & PRINCIPE**

1104 species (Figueiredo et al. 2011). Moderately well-collected?

Exell's *Catalogue of the Vascular Plants of Sao Tome* was published in 1944 (Exell 1944).

A checklist (Figueiredo et al. 2011) has local names, habitat and specimen citations.

#### **SENEGAL**

2086 species (Lebrun 1973). Well-collected.

Treatment in French in the *Flore Illustré du Sénégal* (Berhaut 1974–1988): no keys, but synonymy, full descriptions, habitat, specimen citations, iconography, and many illustrations. The sequence is systematic.

Treated as one of the countries covered by the FWTA.

A checklist (Lebrun 1973) gives specimen protologues and some synonymy and literature.

#### **SIERRA LEONE**

About 2200 species. Moderately well collected.

Treated as one of the countries covered by the FWTA.

## SOMALIA

3165 species (Thulin 2006). Moderately well-collected.

Recent and in-depth treatment in *Flora of Somalia* (Thulin 1993–2006), in English, with keys, synonymy, descriptions, habitat, distribution and many illustrations. The sequence is systematic. Within the volumes blocks of related families are treated; the volumes were published when ready, so not in numerical sequence.

## SOUTH AFRICA

20491 species (Germishuizen et al. 2006). Well-collected, but some high-diversity areas still undercollected?

The *Flora of Southern Africa* (FSA, see ‘main floras’) deals with this extraordinarily plant-rich country (and with Namibia) but less than 20% of this flora has been published; a very rich literature of area floras and field guides makes up for the lack of a complete flora.

An annotated checklist is given by Germishuizen et al. (2006).

## SOUTH SUDAN

2961 species (Darbyshire et al. 2015). Under-collected.

The most recent flora-like account is *Flowering plants of the (Anglo-Egyptian) Sudan* by Andrews (1950, 1952, 1956), but this is very incomplete and based on rather few collections.

An annotated checklist was published by Darbyshire et al. (2015), which emphasizes that large areas of the country and large parts of the flora are not covered by any modern treatment.

Friis & Vollesen (1998, 2005) deals with the specific locality of on the Imatong Mountains.

El Amin (1990) is a partial guide to trees and shrubs of South Sudan.

## SUDAN

2117 species (Darbyshire et al. 2015). Moderately well to under-collected.

The most recent flora-like account is *Flowering plants of the (Anglo-Egyptian) Sudan* by Andrews (1950, 1952, 1956), but this is very incomplete and based on rather few collections.

An annotated checklist was published by Darbyshire et al. (2015), which emphasizes that large areas of the country and large parts of the flora are not covered by any modern treatment.

There are publications on specific localities, such as Quezel (1969) on NW Darfur, Wickens (1976) on Jebel Marra, Léonard (1997, 199a, 199b, 2000) on Jebel Uweinat. El Amin (1990) is a partial guide to trees and shrubs of Sudan.

## SWAZILAND

2118 species (Compton 1976); 2715 native and 110 naturalized (Kemp 1983). Moderately well-collected.

The *Flora of Swaziland* (Compton 1976) is in English, and has short descriptions, habitat and specimen citations; no illustrations. The sequence is systematic.

Kemp (1983) is an un-annotated systematic checklist.

## TANZANIA

11135 species (Q. Luke, pers. comm. Sept. 2015). Moderately to well-collected.

Treated as one of the countries covered by FTEA.

A field guide to moist forest trees (Lovett et al. 2006) treats 658 species.

## TOGO

About 2500 species. Well-collected.

The *Flora of Togo* (Brunel et al. 1984), in French, has short taxon descriptions embedded in the keys, national distribution and specimen citations; no illustrations; does not give the total number of species included. The sequence is systematic.

Treated as one of the countries covered by the FWTA.

## UGANDA

4816 species (Q. Luke, pers. comm. Sept. 2015). Most parts well-collected.

Treated as one of the countries covered by FTEA.

The trees are treated in Eggeling & Dale (1951) but this is now getting out of date; Kalema & Beentje (2012) is an updated checklist-cum-conservation data version of the famous *Indigenous Trees of Uganda*; it treats over 800 species.

Forest trees are treated in Hamilton (1981), dealing with 447 species.

## ZAMBIA

About 5000 species; 6280 taxa (including subspecies and varieties; Phiri 2005). Moderately well-collected.

Treated as one of the countries covered by FZ.

A checklist is given by Phiri (2005).

## ZIMBABWE

About 5500 species. Moderately well-collected.

Treated as one of the countries covered by FZ.

Website (<http://www.zimbabweflora.co.zw>) has 'the intention to create an online flora' (accessed Oct. 2015).

A checklist (Mapaura & Timberlake 2004) gives 5930 taxa, including subspecies and varieties.

## Gaps in our knowledge: under-collecting

Even when a flora or checklist exists for a country, coverage can be incomplete – due to uneven coverage of collecting. Many areas in sub-Saharan Africa are still under-collected (see Fig. 1). Such areas were shown previously on the AETFAT Léonard and Hepper maps of density of African plant collecting (Léonard 1965; Hepper 1979), but were rather generalized. The Kuper map of data deficiency (Küper et al. 2006; Fig. 1) is based on the

well-known Barthlott map of high diversity areas, linked to documented data, and shows (in the darker areas) the under-collected or even un-known areas that coincide with areas of high plant diversity. Such a link is important for conservation, where we like to give priority to such areas of high plant diversity (Kuper et al. 2004), in order to conserve the most species in the most cost-effective way. When such coverage is coupled to complementarity (Vane-Wright et al. 1991) it becomes the most effective way of conserving plants, and therefore conserving the animals that feed on them, and the whole ecosystem involved. This is what I see as the updated version of our AETFAT Léonard and Hepper maps – but brought into the 21st century, and linked to conservation.

## Gaps in our knowledge: taxonomic gaps

Then there are the taxonomic gaps. The easiest way to spot these used to be to check the family you are interested in in Bamps & Degreef (2003), which would show whether such a family had been published in any of the African floras; sadly, this is now 12 years out of date. It would be good to have this updated, although the new data coming out of molecular work, such as that of the Angiosperm Phylogeny Group, have caused many changes about which families genera are arranged into, and the splitting of entire families; it would not be easy to compare the old with the new. Good floras also indicate where gaps in our knowledge remain, despite the taxa concerned being treated in a Flora.

Some taxa have gaps all of their own, because they are difficult to collect (e.g. succulent euphorbias, palms, pandans) or are seen as 'problem' groups, and not collected very much and left to very few specialists (sedges, say, untreated for several floras; or pandans, again). Such groups are often the last in large Flora treatments, too. And let us not forget the Very Large Genera, which need a specialist

	1 <sup>st</sup> vol	Completed	Area in million km <sup>2</sup>	% of area of subsaharan Africa	Total number of species	% of total species in Africa
FEE	1980	2009	1.2	5%	6.027	12%
Fl Somalia	1993	2006	0.6	2.5%	3.165	6%
FTEA	1952	2012	1.8	7.5%	12.383	27%
FWTA	1954	1972	5.0	21%	7.300	16%
Fl Djibouti	1994=	=1994	0.02	< 1%	783	< 2%
Fl Rwanda	1978	1988	0.03	< 1%	2.300	5%
Fl Swazil	1976=	=1976	0.02	< 1%	2.825	6%
Total			8.6	36%	(overlap)	(overlap)

**Table 1.** Completed floras. Data as of October 2015.

Note: not included are national Floras already included in a regional Flora; such countries include Benin, Guinee, Senegal, Togo. The only countries with a complete national Flora and at the same time part of an incomplete regional Flora are Rwanda and Swaziland. Part of a complete regional Flora but as yet without a national Flora are: Burkina Faso, Eritrea, Ethiopia, Gambia, Ghana, Guinee Bissau, Kenya, Liberia, Mali, part of Mauretania, most of Niger, Nigeria, Sierra Leone, Tanzania, Uganda.

	1 <sup>st</sup> vol	% completed	Area in million km <sup>2</sup>	% of area of subsaharan Africa	Total number of species	% of total species in Africa
Consp Fl Ang	1937	33 (pers. estimate)	1.2	5	6.961	15%
Fl Afr Centr	1948	66 (pers. estimate)	2.4	10	10.500	20%
FZ	1960	88 (Timberlake, pers. comm.)	2.6	11	10.610	20%
Fl Gab	1961	50 (Sosef, pers. comm.)	0.3	1.2	7.000	15%
Fl Cam	1963	30?(pers. estimate)	0.5	2	8.300	17%
Fl Moc	1969	?	0.8	3.3	6.000	12%
Fl Cabo Ver	1995	?	0.004	< 0.1	651	1%
FSA	1963	< 20 (pers. estimate)	1.2	5	24.000	52%
Fl Guinea Equ	2008	< 20 (pers. estimate)	0.03	0.1	3.300	6%
Total			9	37.5%	(overlap)	(overlap)

**Table 2.** Floras as yet incomplete. Data as of October 2015.

Note: not included are separate countries included in a regional Flora: Botswana, Burundi, Congo Kinshasa, Cote d'Ivoire, Lesotho, Malawi, Mozambique, Namibia, South Africa, Zambia, Zimbabwe. The only countries with a complete national Flora and at the same time part of an incomplete regional Flora are Rwanda and Swaziland.

	Area in million km <sup>2</sup>	% of area of subsaharan Africa	Total number of species	% of total species in Africa
Chad	1.3	5%	2.256	5%
CAR	0.6	2.5%	3.600	7%
Congo Braz	0.3	1.2%	6.000	12%
Guinee Eq	0.03	< 1%	3.300	6%
Namibia	0.8	3.3%	3.961	8%
Sao Tome & P	0.001	< 1%	1.104	2%
Sudan	1.9	8%	2.117	5%
South Sudan	0.6	2.5%	2.961	6%
Total	5.5	23		

**Table 3.** Countries without any flora. Data as of October 2015.

or group of specialists to work on them for long periods – you don't solve problem groups like *Aloe* (>550 species) or *Vernonia* (>300 African species) in a year or two. The proper way of dealing with such very large genera requires long-term institutional support, as well as collaboration. Examples of successful projects on large genera include Goldblatts work on Iridaceae, Roux's work on ferns, and the projects of the Rubiaceae consortium, Acanthaceae consortium and eMonocot consortium.

### Plugging the gaps: under-collected areas

Plugging the gaps caused by under-collecting is relatively easy, though it may be very time-consuming: all you need is the knowledge of where such gaps are, plus a period of political stability in the area concerned; and, of course, a fieldwork budget – not the easiest thing in a time of financial austerity.

Fieldwork is essential to good botany. You can do much taxonomy based in a good herbarium, because many of them are so rich (based as they are on vast amounts of fieldwork by our predecessors!), and a good library and/or the Biodiversity Heritage Library (BHL) on your computer; but to get a 'feel' for the plants you are interested in you need to see them in their

natural habitat. You will see how they vary according to local conditions, which will result in a much better morphological description; you will work with local colleagues, who will teach you new things, as you hopefully will also teach them a bit; and you will see those majestic rainforests, and those wide African plains, as well as the people who cut the forests to feed their children, the animals grazing the plains, and the stars over the night mountains.

### Plugging the gaps: the taxonomic gaps, and the taxonomic impediment

The plugging of taxonomic gaps is relatively straightforward, as it only requires dedicated botanists to produce revisions, monographs and flora treatments. So why are some of these gaps still there? Sometimes the reasons are financial – fieldwork comes pretty low on most institutional priority lists, and government support for taxonomy is in decline (Paton et al. 2008; Pimm et al. 2014). And that is when there *is* a group of taxonomists to ask for the funds in the first place – because the well-publicized Taxonomic Impediment is often the main reason for big gaps.

Many people rely on plant taxonomists to provide data on which their disciplines rely: biodiversity scientists and conservationists, DNABarcoders and phylogenists, biochemists,

ethnographers, and at times even the police, or politicians when it comes to deciding on habitat protection; and big industry, when it comes to environmental impact assessments.

The shortage of trained taxonomists and curators to fill this need has come to be known as the taxonomic impediment. There is a limited pool of people who can provide such data. Traditional taxonomy, from fieldwork to writing revisions, checklists and conservation checklists or even Red List assessments, is looked down upon as old-fashioned, and is underfunded. Courses in taxonomy are disappearing from many Universities. And still the remaining taxonomists are being seen as service providers, feeding names to **real** researchers. And we are desperately trying to describe all those new species, fit them into stable patterns, write keys on how to distinguish them, work out synonymies, as well as name the voucher specimens for a host of other researchers who rely on us.

Cyberstructures and automation cannot replace taxonomy; they can enhance it, but it still needs real people with real knowledge to name the plants, write the floras, establish the synonymies. Chloroplast DNA is used widely to infer plant phylogenies at different taxonomic levels - and can be extremely useful at the higher levels of taxonomy. But that doesn't reduce the essential need for alpha-taxonomy as well. It is essential to have solid taxonomy at the species level, and I mean old-fashioned fieldwork combined with herbarium studies, resulting in flora treatments and regional monographs. Without such old-fashioned results, all higher taxonomy is based on quicksand — you need good vouchers for your chloroplast DNA work; you need a species framework to decide where to cast your phylogenetic net; you need people to name your vouchers and find your material.

Alpha taxonomy is still a *sine qua non*, because it underpins all other work; and it is far from complete, at both continent and family levels. Such alpha-taxonomy can be made more accessible by modern methods, and this

is already happening for some floras and databases: *Flora Zambesiaca* and *Flore d'Afrique Centrale* are partly online; the International Plant Name Index (IPNI), the African Plant Database, and Tropicos are examples of over-arching and accessible tools for taxonomists as well as end-users.

It is vital that a new generation takes over, using modern methods in communication to (maybe) speed up the completion of floras and the popularization of the importance of wild plants.

### Plugging the gaps: conservation

In a very practical manner, floras combined with fieldwork and the input of local colleagues lead to conservation redlisting. The floras provide the basic distribution data and habitat data to give priority to those species that are limited in distribution and ecological niche; herbarium specimens give data for plotting the extent of occurrence (EOO) and area of occupancy (AOO), which are so necessary to make a complete IUCN assessment; and people who know the species in the field contribute their knowledge of population size and threats. All this leads to an argued and fact-based IUCN Red List of threatened species assessment (see [iucnredlist.org](http://iucnredlist.org)).

This is important, very real work: a Kenyan colleague of mine does Environmental Impact Assessment work for large industrial projects in Africa, and if a species does not appear on the official IUCN Red List the companies involved do not care; but when such species **do** appear on such lists, when a tree is listed as Critically Endangered, such companies **have** to pay attention (Vorontsova & Luke, in press). And Governments base conservation decisions on such Red Listings, too. This is just one extremely practical aspect of taxonomic work.

As an example, much of the work of the East African Plant Redlisting Authority, which has RedListed over 1850 species so far, has a solid base in the *Flora of Tropical East Africa*, the *Flora of Ethiopia and Eritrea* and the *Flore*

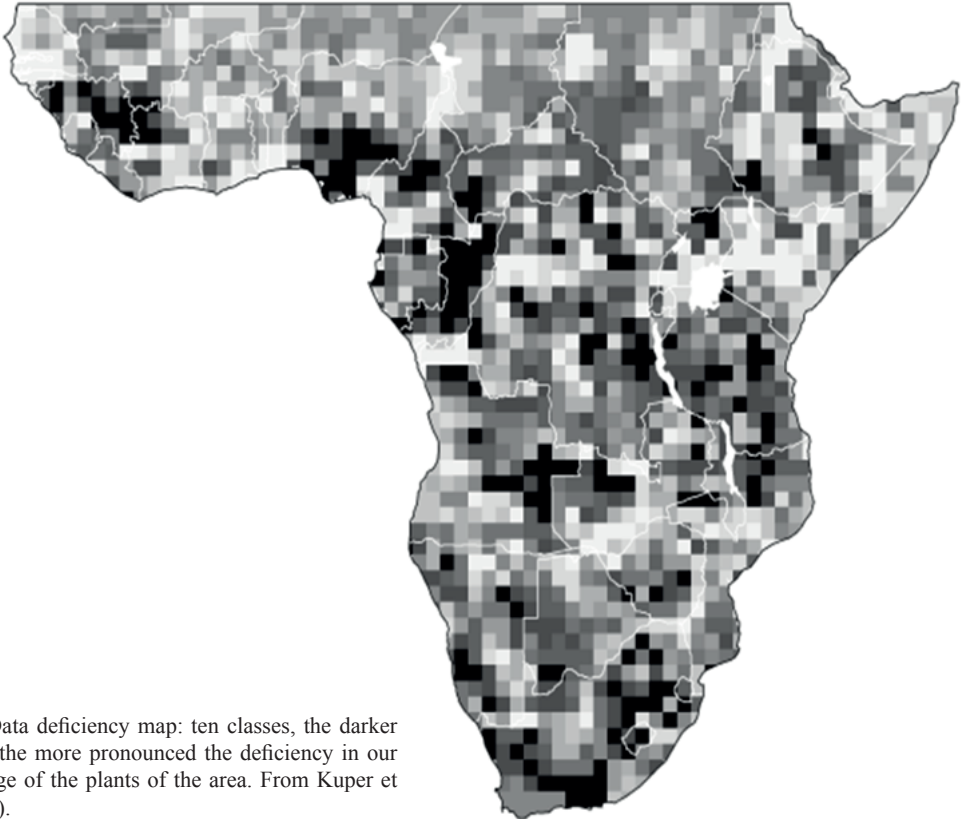


Fig. 1. Data deficiency map: ten classes, the darker the cell, the more pronounced the deficiency in our knowledge of the plants of the area. From Kuper et al. (2006).

*d’Afrique Centrale*. It also has an essential part of its base in its’ members fieldwork experience!

### **The future of floras – should there be one?**

Floras are seen as old-fashioned. They are cumbersome projects, taking up large amounts of botanists’ time, as well as resources. In peoples minds, they are still linked with colonial projects – dinosaurs from the past, which take forever to complete, and are not very accessible for the information other disciplines need from botany. Surely, by now, with the internet and other resources, we can move on and be more practical!

I agree that floras are old-fashioned, but I would argue they are still essential for progress

on our knowledge of wild plants. In my own taxonomic life I have authored and co-authored checklists, monographs, revisions, flora parts, conservation checklists and field guides. I think all of these have a role in gap-filling. It is so much more easy to collaborate, with modern methods, and so much more productive, too.

I remain convinced that floras are the place where it all comes together: they synthesize our knowledge, building on those basic building blocks, the checklist, and on those hard-core taxonomic blocks, revisions and monographs. They link all kinds of data in one unified format, and clearly show where are the gaps in our knowledge. Having to write keys to all of the taxa also shows up taxonomic problems and possible synonymies: key-writing concentrates the taxonomic mind more than anything else, in my opinion!

Once the floras are written, they can be used in many ways. They are the tool that allows identification, and therefore access to a vast literature. They link distribution data to habitats, they provide baseline data for all future conservation assessments, they form the basis for the writing of more user-friendly field guides.

The world-wide web has some excellent tools to help us speed up the writing process, and to collaborate with colleagues from all over the world. I will just mention the main ones: IPNI ([ipni.org](http://ipni.org)), which gives the names and basic bibliographic data of all species ever published; JSTOR ([jstor.org](http://jstor.org)), which gives access to scans of herbarium specimens, extracts from regional Floras, journals and books; TROPICOS ([tropicos.org](http://tropicos.org)), with specimen data from the Missouri Botanical Garden collections; and BHL ([biodiversityheritagelibrary.org](http://biodiversityheritagelibrary.org)), with free access to much biodiversity literature.

These are all global sites, but we also have much that is purely African in scope that we can be proud of. Growing from the wonderful accomplishments of Lebrun & Stork, there came into being the brilliant and highly useful African Plant Database (<http://ville-ge.ch/musinfo/bd/cjb/africa/recherche.php?langue=an>), which provides a checklist of all African plants, gives the current status and synonymy of taxa, notes on habit, habitat and distribution, as well as distribution maps for most of them, and links to other sites for specific taxa (JSTOR, various Floras, TROPICOS, the Senckenberg site with photos). The Senckenberg site ([africanplants.senckenberg.de](http://africanplants.senckenberg.de); Dressler et al. 2015) is an ever-expanding photo database with many images of seed plants and ferns. In some of these cases Africa is way ahead of the rest of the World!

## Conclusion

I think taxonomy in Africa is in a bad state, with a serious case of the Taxonomic Impediment, including chronic under-funding, and with

extinction of plant species possibly going faster than discovery. At the same time, taxonomy in Africa is an excellent state because, despite these impediments and problems, we are producing floras, checklists and Redlist assessments, overviews and easy-access databases. We can also add to the positive side of the balance sheet a lot of collaboration, interconnectivity and networking, not least through shining examples such as the AETFAT conferences, the African Plant Database, and the collaboration on the floras that are still being published. And what is science about? The essence of science is communication; and the use of science is that it can be used for practical purposes.

There are still plenty of gaps, so there is plenty to work on. My personal views on priorities are the practical ones, the basic ones, so that we and others can use our data to improve focused conservation and use of wild plants. We can build those overview products such as floras and conservation checklists, and improve their accessibility. We should fill those gaps, geographic and taxonomic: the under-known hotspots through targeted fieldwork, the large and difficult genera through networking and collaboration. We should complete RedList assessments for **all** regional endemics and other narrow endemics.

And we should make clear to the people who use our services and products that taxonomy is an important and vital building block in helping Africa build a sustainable future, and that floras are one of the main entry points to the data we produce.

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