FROM CHECKLISTS TO AN E-FLORA FOR SOUTHERN AFRICA: PAST EXPERIENCES AND FUTURE PROSPECTS FOR MEETING TARGET 1 OF THE 2020 GLOBAL STRATEGY FOR PLANT CONSERVATION[1]

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Abstract

The exceptional botanical wealth of southern Africa has been known internationally since the early 17th century. However, it is only during the past 25 years that a succession of regional floristic checklists has been published, culminating in one for southern Africa (Namibia, Botswana, Swaziland, Lesotho, and South Africa) (Germishuizen & Meyer, 2003) and another enhanced with primary biological information such as growth form, plant height, and altitudinal range occurrence for South Africa (Germishuizen et al., 2006). These printed products (Germishuizen & Meyer, 2003; Germishuizen et al., 2006) delivered floristic checklists for southern and South Africa, respectively, on time for achieving Target 1 of the 2010 Global Strategy for Plant Conservation (GSPC). These works reflected the cumulative work of several generations of taxonomists, collectors, recorders, and databasers and were based on extensive regional herbarium collections. Two additional goals are now required for the first 2020 GSPC Target, namely adding descriptive and other Flora-style information, and disseminating such information electronically.

Key words: E-taxonomy, Flora of southern Africa (FSA), Global Strategy for Plant Conservation (GSPC), online flora, South Africa, southern Africa.

Consideration of the history of Flora writing for, and in, southern Africa is here undertaken to determine the likely rate of progress with producing an e-flora for the region. One questions whether delivery should or could proceed through conducting an established science in an established way. If a new way of Flora production is to be embraced, for example, through e-taxonomy, then this will inevitably require the overcoming of institutional, social, and technological challenges. Southern Africa is here defined as the Flora of southern Africa (or FSA) region, that is, Namibia, Botswana, Swaziland, Lesotho, and South Africa. We argue that South Africa has been well placed to play a leading role in transforming floristic texts produced prior even to the onset of the world wide web into web-based content that includes nomenclatural and descriptive content as well as plant identification tools.

Brief History of Floras in Southern Africa

Following publication of his *Flora Capensis* in 1823, Carl Peter Thunberg (1743–1828) became widely known as the "Father of Cape Botany." This major work on the Cape flora was preceded by the publication of two volumes of its forerunner, *Prodromus plantarum Capensium*, which Thunberg produced in 1794 and 1800, respectively. Describing just less than 2800 species, Thunberg's *Flora Capensis* was a major reference on the flora of the Cape for the better part of the ensuing 100 years (Gunn & Codd, 1981; Fraser & Fraser, 2011).

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However, this "primary" Flora was antecedent to the *Flora Capensis* initiated by Irish academic William Harvey (University of Dublin) and German apothecary Otto Sonder (Hamburg) (Hall, 1977), which represented the first true Flora for South Africa. It was started privately in the years 1859–1865, within which period the first three volumes were published (Harvey & Sonder, 1859–1860; 1861–1862; 1864–1865). The first significant book on South African botany published on South African soil, *The Genera of South African Plants*, was produced by Harvey about 20 years earlier in 1838 (Bullock, 1978; Gunn & Codd, 1981: 180). This marked the year that the comprehensive exploration of the South African interior gained momentum through a northerly and easterly Great Trek undertaken by the Boers who were, mostly, dissatisfied with British colonial rule following the second and final British invasion in 1806. Sir William Hooker was attributed with "urging its [*Flora Capensis*] prosecution on its originator, Dr. Harvey," although Kew was not at first formally involved in this colonial Flora (Anonymous, 1861: 259). The Flora series lapsed with the death of Harvey in 1866 and Sonder's disengagement from the project, when in 1875, he sold the greater part of his Cape Herbarium (Gunn & Codd, 1981). Sonder died in 1881, by which time the Philosophical Society of South Africa was already prompting a local dignitary to motivate for the completion of the Flora (Hall, 1977). After a lapse of 15 years, the Flora resumed in 1896 under the leadership of the Royal Botanic Gardens Kew, with the major portion of the work completed by N. E. Brown and C. H. Wright of that institute. A number of South African botanists also contributed treatments, however, including H. Bolus, F. Guthrie, E. Stephens, H. Pearson, and E. Phillips (Thiselton-Dyer, 1925; Phillips, 1930). The final fascicle of *Flora Capensis* (Hill, 1933), on gymnosperms, was printed as a supplement to Volume V. In total, 11,731 species were covered in seven volumes for the area chiefly south of the Tropic of Capricorn. At the time, the series was considered by some, such as J. Burtt Davy who was quoted from his correspondence, as "a permanent and sound foundation for a series of Local Floras of South Africa," and upon which he based his manual of plants of the Transvaal and Swaziland (Thiselton-Dyer, 1925: 291).

In February of 1955, just over 20 years after the final treatise in the *Flora Capensis* series appeared in print, the Botanical Survey Advisory Committee in South Africa unanimously supported the concept of producing an FSA to replace *Flora Capensis*, which was by then perceived as outdated. It was anticipated at the outset that the project would take about 40 years to complete, eventually covering 20,530 species in 180 angiosperm families. The Minister of Agriculture approved the project in principle, on the condition that the work be published in both Afrikaans and English and that no additional staff be asked for by the Botanical Research Institute (BRI; Verdoorn, 1958). The project was to cover the territories known today as South Africa, Lesotho, Swaziland, and Namibia (Marais, 1958) with the sequence of completion of volumes or fascicles in line with taxonomic revisionary work already in progress. The region then known as the Bechuanaland Protectorate (today Botswana) was to be covered by the Flora Zambesiaca, a project started in earnest during August 1956 and anticipated to take 20 years to complete (Wild, 1958), but which is still in progress. Wild (1958: 54) observed that the proposed Flora Zambesiaca represented "perhaps a more direct collaboration between an independent African herbarium [SRGH] and the European herbaria than in other [Tropical African] Floras which are more definitely the products of European centres." He also pointed out that the boldness of plans for a Flora that would cover what is today Zimbabwe, Botswana, Zambia, Malawi, and Mozambique prompted the South Africans to broaden their floristic vision. Wild (1958) reported that R. A. Dyer, then Director of Botanical Services for the Department of Agriculture in Pretoria, had planned for some years to complete the *Manual of the Flowering Plants and Ferns of the Transvaal with Swaziland, South Africa*, two fascicles of which had been produced by Burtt Davy (1926, 1932). However, learning of the scope of the Flora Zambesiaca project, Dyer decided rather to co-motivate for a much more ambitious FSA. This Flora was to complement the Flora Zambesiaca and the *Conspectus Florae Angolensis* and with them provide a complete floristic review of the whole area south of the Congo and Tanzania (Dyer, 1977).

The first FSA volume was generally well received on its publication in 1963, with a reviewer (Bullock, 1965: 224) observing that "throughout the text there is most encouraging evidence of the effectiveness of the Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale (AETFAT), the main objects of which are to encourage international discussion of taxonomic problems and to attain a high degree of uniformity in both taxonomic treatment and nomenclature in all the regional Floras currently in preparation." Dyer (1977) similarly acknowledged the role of AETFAT, which first convened in Brussels in 1951, in providing impetus to the preparation of regional Floras. Not surprisingly, AETFAT meetings

have provided a regular opportunity for taxonomists to present on progress with the African Floras (e.g., Codd, 1965, 1968; Killick, 1971, 1976 for the FSA). Although AETFAT has continued to meet every three or four years over the past six decades, Flora reports have appeared less regularly in the proceedings resulting from recent conferences (sometimes presented only as posters), most notably for those Flora series that have progressed rather slowly.

Other than the FSA series undertaken by the then BRI of South Africa, often with overseas international collaborators, workers within several of the countries included in the geographical scope of the FSA contributed significantly toward Flora studies for their respective nations. Compton (1976) delivered *The Flora of Swaziland*, which treated 2118 species of flowering plants, providing brief descriptions as well as taxonomic keys, collection vouchers, and notes on ecological and taxonomic matters. A subsequent updated checklist (Braun et al., 2004) enumerates 3441 plant taxa from Swaziland, reflecting substantial botanical exploration of that country during the past four decades; Compton's Flora nonetheless remains a useful basis for delivery on Swaziland's Target 1 for GSPC by 2020. The Flora of South West Africa (FSWA), of the country known today as Namibia, was previously treated as a prodromus, a preliminary treatise respecting a subsequent more elaborate work as was intended by Merxmüller (1968). His part 1 (of five, by 1972) first appeared in 1966, some 15 years after the work initiated, it was anticipated that it would be possible to complete the entire work within three years thereafter (Merxmüller, 1968). Ultimately, publication would proceed over six years (Merxmüller, 1966–1972) and represent the treatment of ca. 4300 taxa from an area of 824,268 km^2. The early completion of Merxmüller's prodromus has well placed the taxonomic community in Namibia to further research and manage its flora, a good reminder that even the completion of a flora's prodromus, as would be the case with a Flora, is a means to further ends and not just an end in itself. Among the 10 participants in the Southern African Botanical Diversity Network (SABONET) program, Namibia has been outstanding in its delivery of useful products. It was the first to produce a country plant checklist (Craven, 1999) and a country-level plant Red Data Book (Loots, 2005). Presently, a modern, English-language Flora of Namibia is under development.

By the late 1970s it was realized that in order for the volumes to appear in the form planned initially, the progress with the FSA would need to proceed much more rapidly (see Dyer et al., 1963: vi–vii). Accordingly, the format of the Flora was modified (descriptions were shortened and specimen citations simplified) to speed up production without the loss of essential information, and fascicles with a minimum of 50 species were considered for publication (Leistner, 1983). This necessary change reflected a flaw in the original Flora planning process, which led to components of volumes being completed but not printed, as the balance of the anticipated contents was not ready for publication. As part of efforts to enhance the publication rate of small, but publishable units submitted to the FSA editorial office, the series "FSA contributions" within *Bothalia* was started in the mid-1990s (see, e.g., Smith, 1995a, 1995b). As conceived, the Flora was to appear in 33 volumes with some volumes split into a maximum of four parts for very large families, for example, Asteraceae, such that between 300 and 800 taxa would be treated per volume. Although information for inclusion in the planned FSA was considered by Verdoorn (1958: 74) to be "on the generous side," standard Flora-style information was ultimately presented. Each taxon and its relationships in both southern Africa and adjoining territories were considered critically, and taxonomic descriptions, keys, selected citations of specimens and literature given, along with distributional information, synonyms, nomenclatural types, notes, and at times illustrations.

At the present time, ca. 18% of the 24,393 plant taxa known from southern Africa (Germishuizen et al., 2006) have been treated in the FSA, and this after 55 years of work. The vast majority of treatments deal with South African species, which were recently enumerated at 22,604 taxa (Germishuizen et al., 2006). By 1970 alarm bells were already ringing, and Killick (1971: 77) reported to AETFAT that at the rate of progress then evident, although parallel monographic work was not included in the FSA, "the Flora will take another two centuries to complete." Five years later Killick (1976: 633) balefully projected that the Flora would be completed in 2345, although if one included the species already completed in the volumes then being tackled "the situation looks a trifle brighter: 8% completed and final date 2151." De Winter (1970) had estimated that five fully trained taxonomists dealing with 150 species per year would take only 18 years to complete the FSA. However, Killick (1971: 77) pointed out that although seven professional botanists were working on the Flora team, none worked full time on the project, resulting in "a most unsatisfactory state of affairs." Leistner (1983) appealed to members of AETFAT to cooperate on the FSA, noting that 48

taxonomists from outside the BRI of South Africa were already collaborating. However, it is likely that the apartheid policies of the then government of South Africa deterred participation, and within a few years an academic, cultural, and sports boycott of the country was in full motion. At the time, the other major African floras (Flora Zambesiaca, Flora of Tropical East Africa) were also struggling to improve their slow production pace, and most European taxonomists were already committed to those projects.

Collaboration North-South and South-South

Most large Flora projects, both historical as well as current, are clearly undertaken by major international herbaria such as those of the Royal Botanic Gardens, Kew (K) and the Missouri Botanical Garden (MO). Indeed, significant taxonomic achievements that yield regional Floras or checklists in sub-Saharan Africa have most often resulted from collaborations between north and south. The FSA is exceptional in that it has been attempted by a developing nation (South Africa), albeit to date with only partial success.

The hugely successful SABONET program, funded by the Global Environment Facility (GEF) and the United States Agency for International Development (USAID), developed through the United Nations Development Program (UNDP), but implemented through the then National Botanical Institute (NBI) of South Africa, represented an almost exclusively south-south collaboration where the main aim was capacity building, but the results included national plant checklists. In the first decade of the 21st century, the nature of such formal collaborations has taken the form of online e-taxonomy, where maximal use of the internet has provided access to regional inventories. In southern Africa, the most recent of these has been the production of inventories of plant diversity and common names for Angola (Figueiredo & Smith, 2008, 2012). The plant diversity inventory was supplemented by a wealth of biodiversity data available electronically and through the international collaboration of 30 scientists (Smith & Figueiredo, 2010). Online resources accessed in the course of this floristic work are detailed by these authors.

One of the most significant north-south projects for Africa to have been completed in recent years is the first-ever angiosperm checklist and database for sub-Saharan Africa (Klopper et al., 2006). The African Plant Checklist and Database project (APCD) is a collaboration between the South African National Biodiversity Institute (SANBI) and the Conservatoire et Jardin Botaniques de la Ville de Genève (Switzerland) and is available as a regularly updated online searchable database (African Plant Database, 2013). In line with the objectives of AETFAT, the APCD checklist was conceived in 1994 during the 14th congress of that Association; the full history of the project has been documented by Gautier et al. (2006).

Global Strategy for Plant Conservation Target 1 for 2020

The original Target 1 of the Global Strategy for Plant Conservation (GSPC; United Nations Environment Programme [UNEP], 2002) was conceived as "a widely accessible working list of all known plant species, as a step towards a complete world Flora." This target was considered well addressed when a global world plant list became available (Plant List, 2010) in late December 2010. In southern Africa, such a target had been achieved years earlier with the national checklists produced within the scope of the SABONET program (Craven, 1999; Braun et al., 2004; Kobisi, 2005; Setshogo, 2005; Germishuizen et al., 2006) and by the global sub-Saharan checklist for flowering plants (Klopper et al., 2006). Further progress toward delivery on this target for several components of the South African flora prior to 2010 has been provided by Smith and Smith (2006).

Looking ahead to the next stated interval, 2011–2020, the Global Partnership for Plant Conservation (GPPC, 2010) focuses on the enhancement of Target 1 with the following goals in mind: a) to add a more complete description and other Flora-style information to the checklist; and b) to make the working list "more useful, accessible, and functional for end-users" by disseminating such information electronically. Therefore, the first target of the GSPC aims now to produce an electronic Flora for all the world's plants by 2020. Significantly, the Secretariat of the Convention on Biological Diversity (SCBD, 1992 on) has unambiguously taken a dim view of the generally slow progress with Flora production globally, by challenging the taxonomic fraternity to produce an electronically accessible Flora for the world within the next seven years.

A recent assessment of the state of botanical research in South Africa (Bredenkamp & Smith, 2008) has highlighted local concerns related to the advancing group age of practicing botanists coupled with an inadequate rate of training and mentoring of young scientists. This gap in age and training is reportedly particularly acute in the formal South African systematics and taxonomic community (Herbert et al., 2001). Nonetheless, as Joppa et al. (2011) have pointed out in their global analysis of rates of species descriptions, systematics research continues

apace, despite such contrary reports on the dissolution of taxonomic capacity. Joppe et al. (2011: 551) determined that "the numbers of [flowering plant] taxonomists are increasing. . .as are the numbers of taxonomists who are the senior authors on species descriptions." This led to their conclusion that "taxonomic description no longer belongs to those who do nothing else; species description is much more widely practiced." However, it must be noted that there is a great difference between describing one new species and producing a taxonomic revision for a group of species, the former being a task eagerly done by amateurs while the latter requires greater perspective and formal training. Regardless of who undertakes the taxonomic work, a strategy and supporting implementation plan for South Africa and southern Africa is required, if Target 1 of the revised GSPC is to be achieved by 2020.

The Way Forward in Southern Africa

The sound nomenclatural and taxonomic platform provided by the APCD supports not only ongoing floristic work in sub-Saharan Africa, but also the e-taxonomic and e-Flora efforts that will be needed by the constituent/participating African countries to support delivery on Target 1 of the 2020 GSPC. This target toward the completion of an accessible or online Flora of all known plants in the world has to build on the achievement of the 2010 target, namely, the working list of known plant species (<https://my-plant.org/news/plant-list-working-list-all-plant-species>). The structure and form of this online Flora are as yet uncertain, even in relation to the scope of content. The current authors consider that it should largely align with traditional concepts of a Flora (see e.g., Harvey & Sonder, 1859–1860) by including descriptive information and identification tools. The traditional format, at least in Africa, has been fairly uniformly modeled and typically concurs with Kirkup et al. (2005: 457), who consider a Flora to "provide an inventory of plants occurring in a particular geographic region and provide a means to identify these plants." Descriptive content and identification tools, such as dichotomous keys, are central to this definition.

Historical, colonial Floras drew on a concise format and taxonomic structure, were mindful of production costs, and provided the minimum needed to allow for the identification of a specimen drawn from, importantly, the defined geographic range for that Flora. With floristic texts and visual resources logarithmically expanding online (cf. Encyclopedia of Life [EOL], now including over a million species pages [Encyclopedia of Life, 2013]), one questions whether the traditional Flora format needs to be maintained, for the historic objectives can now be realized in a completely different way, through a product that might well look and feel vastly different. Importantly though, if a new way of writing and constructing a Flora is to be embraced and Target 1 of the 2020 GSPC achieved, taxonomists and their institutions will need to shift their mindsets, technology base, and approaches to collaboration within an e-taxonomy frame. Significant projects are already underway to harness the interest, expertise, and goodwill of large groups of taxonomists around the globe. The eMonocot initiative (eMonocot, 2013) is one such project that, through the web, will provide information such as up-to-date checklists, nomenclature, taxonomic descriptions, plant images, and identification guides, as well as geographical, ecological, DNA sequence, and conservation data. This is all structured around a taxonomy derived from the online World List of Monocotyledons (2012), which comprise an estimated 20% of flowering plants. If successful in capturing the anticipated data for 70,000 monocot species by 2020, an online world Flora is arguably expanded toward about one fifth of the global GSPC Target 1.

A project to digitize published African Floras was initiated at Kew 10 years ago, with the aim being to improve the accessibility and utilitarian value of the included plant species information (Kirkup et al., 2005). Similar projects have been developed elsewhere, such as the eFloras project hosted by the Missouri Botanical Garden and the Harvard University Herbaria (Brach & Song, 2006; eFloras, 2013). This website includes checklists and Floras for flowering plants and mosses from China, Nepal, Chile, Ecuador, Missouri, and North America, simply the diverse floristics products of active institutional programs. Most of the early e-Floras such as these facilitate access to information published in particular Flora volumes where access is by a quick search by scientific name, sometimes also by synonym, geographical area, or habitat. As indicated by Kirkup et al. (2005), reflecting changes or additions to the published text for the online version of Flora Zambesiaca were out of the scope of these projects. Interrogating these e-Floras will be the same as consulting printed versions of the Floras in a library, but quicker and more globally accessible. Links to other databases for updated nomenclature are sometimes provided, but such searches may yield irrelevant or inadequate information for the taxon being searched. More recently, other e-Floras have been established, such as the Flora of New Zealand (Flora of New Zealand Committee, 2013), where

information from the original published Flora is dynamically supplemented with data from other sources and with links to other websites. In the near future, it is expected that e-Floras will evolve further, with direct links to information associated with each accepted plant name, and synonymy becoming standard practice. The integration of images of living plants and herbarium specimens (including types) and protologues in an e-Flora is now dramatically achievable. Furthermore, published information from related fields, such as ecology and ethnobotany, where names that are no longer accepted may be used, can also be linked and displayed. This would eventually transcend the function of e-Floras from plant identification tools to plant information systems (enter the ambitious EOL project). This can only be achieved through a collaborative consensus, integrating data from a vast array of different e-sources and with the allocation of resources especially to the most biodiverse areas (Paton, 2009).

The question is then one of how countries such as South Africa should approach Target 1 in order to be able to report at a national level on acceptable country- or regional-level progress toward this target of the GSPC. Whether a taxon-level approach, a geographic approach, or both, is adopted will depend on unfettered access to international initiatives such as eMonocot and its associated e-tools (e.g., the scratchpads so effectively utilized in eMonocots), and on continued, even accelerated progress with traditional Floras or in some instances (e.g., Namibia), development of Floras from their associated prodromi.

During the next eight years South Africa will adopt a dual-pronged approach in evolving e-taxonomy opportunities and existing commitments to provincial and biome-focused Floras, a number of which have already been completed. As early as the 1970s it was realized that the slow progress of the tradition-based FSA would take centuries to complete, and through the efforts of Bond and Goldblatt (1984), the first Flora-style treatment of the Cape Floristic region was published. This work has since seen a second comprehensive update (Goldblatt & Manning, 2000), with a third version now in print production. Similar but with a slightly different style and content, Retief and Herman (1997) produced a taxonomic treatment of the plants of the northern provinces of South Africa. Although the two regions, separated by South Africa's arid, karroid interior, have some species in common, the intelligent digitization of both tomes would provide a significant e-backbone for about 10,000 South African plant taxa. In addition, Retief and Meyer (in prep.) have made significant progress with Plants of the Free State, Snijman (in prep.) with the greater Cape Flora, including the succulent karoo biome, Bredenkamp (in prep.) with the Eastern Cape Flora, and the Northern Cape Flora (Magee & Boatwright, in prep.) having been initiated. This leaves only South Africa's eastern seaboard, essentially from the Drakensberg eastward to the KwaZulu-Natal coast, as lacking treatment. This should offer few challenges, though, as treatments of many species of that subtropical province can be derived from the treatments of the bordering Eastern Cape, Free State, and northern Provinces. These treatments will require significant work to harmonize them across the various in-country regions and to include traditional Flora content that has been occasionally omitted, ranging from protologue and type information, nomenclatural synonymy, as well as adequate identification keys and plant descriptions. It is arguably easier to equalize the treatments than to generate them afresh. The task has been made easier by the availability of much of the necessary information online. It is envisaged that a national e-Flora for South Africa will build from these in-country Floras and various internet resources. These range from taxonomic databases, such as the APCD, JSTOR Global Plants (2013), Kew's World Checklist of Plant Families, the International Plant Names Index (IPNI), and TROPICOS, and also extend to general plant websites such as Plants of Southern Africa (POSA; 2009). An electronic platform can then link all existing information, with additions of original content such as identification tools and distribution maps.

The other southern African countries have much lower plant diversity than that of South Africa (viz. Botswana: 2151 species, Namibia: 3961, Lesotho: 1591, and Swaziland: 3400; Golding, 2002). Electronic Floras for Botswana and Namibia are likely to be produced as outputs of current Flora projects (Flora Zambesiaca and Flora of Namibia) if these reach their end before the 2020 deadline. For Lesotho and Swaziland, e-Floras can be relatively easily accomplished in collaboration and through linking to the resources of the South African e-Flora. Successful delivery of e-Floras in southern Africa will not only require in-country, regional, and international coordination and collaboration with relevant planning, but should also anticipate that developments in information and communication technology (ITC) over the next eight years will provide as-yet unforeseen advantages and tools to develop online Floras.

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