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The South African National Biodiversity Institute (SANBI) and its national botanical gardens: a historical review

Ramagwai Joseph Sebola[a,b,*], Christopher K. Willis[a]

[a] South African National Biodiversity Institute, P/Bag X101, Pretoria 0001, South Africa
[b] School of Animal, Plant and Environmental Sciences, P/Bag 3, University of the Witwatersrand, WITS, Johannesburg 2050, South Africa

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ABSTRACT

The South African National Biodiversity Institute (SANBI) has existed in various forms over two centuries, during which it has remained at the centre of botanical exploration and scientific research in South Africa. With a network of eleven national botanical gardens covering ca. 7 710 hectares of conservation estate and representing seven of the nine biomes in South Africa, SANBI is probably the only institution worldwide that manages such a large network of botanical gardens under a single organisation. Building on previous accounts of the Institute, in this review we highlight the historical insights and critical role played by SANBI in advancing botanical research and knowledge through peer-reviewed publications, human capital development, its network of botanical gardens and various research initiatives. The successful implementation of the National Botanical Gardens Expansion Strategy (2019–2030) will lead to SANBI's presence through a national botanical garden in each of South Africa's nine provinces. The natural history collections of SANBI feature mainly plant specimens housed in three herbaria (Compton Herbarium, KwaZulu–Natal Herbarium, and Pretoria National Herbarium) with a combined estimated holdings of 2.2 million specimens, inclusive of 25 000 type specimens to which scientific names of species are permanently tied. SANBI's efforts towards plant species restoration and conservation are complemented through seed storage facilities at SANBI's Wild Plant Seed Bank (currently ca. 6 637 seed accessions are stored, representing 4 611 plant species). For the past five years ending 2024, SANBI tallied a cumulative 648 peer reviewed publications in ISI journals, with an annual average of 130 publications. SANBI's key science-based legislated mandate outputs remain the National Biodiversity Assessment, Plant Red Data List and assessments of threatened species, the National Species Checklists (for Animals and Plants), the status reports on Biological Invasions, and genetically modified organisms (GMOs) that are released into the environment. These, and many other outputs inform biodiversity planning and monitoring in South Africa. Through its concept of 'Gardens of the Future', SANBI is poised to be a national hub of botanical research and to play an even more pivotal role in biodiversity conservation and education, human capital development and a 'go-to' institution for science based-solutions in biodiversity planning, management and monitoring.

1. Introduction

The origins of the South African National Biodiversity Institute (SANBI) can be traced to 1903 although some of its precursor organizations were established much earlier such as the South African Museum Herbarium (SAM) which was established in 1825, and the Pietermaritzburg Botanic Garden (now the KwaZulu-Natal National Botanical Garden) established in 1874 (Fig. 1). Historically, the legislative mandate of SANBI covered only plant diversity, and SANBI remains the only institution in South Africa mandated through the National Environmental Management: Biodiversity Act No. 10 of 2004 (NEMBA) to manage, maintain and develop national botanical gardens. According to Section 11 of NEMBA, SANBI specifically must, amongst others, manage, control and maintain all national botanical gardens; must establish facilities for horticulture display, environmental education, visitor amenities and research; must establish, maintain, protect and preserve collections of plants in national botanical gardens; must collect, generate, process, coordinate and disseminate information about biodiversity and the sustainable use of indigenous biological resources, and establish and maintain databases in this regard; may establish, manage, control and maintain herbaria (and collections of dead animals); must coordinate and promote the taxonomy of South Africa's biodiversity; and may undertake and promote research on indigenous biodiversity and the sustainable

* Corresponding author at: South African National Biodiversity Institute, P/Bag X101, Pretoria 0001, South Africa.
E-mail address: R.Sebola@sanbi.org.za (R.J. Sebola).

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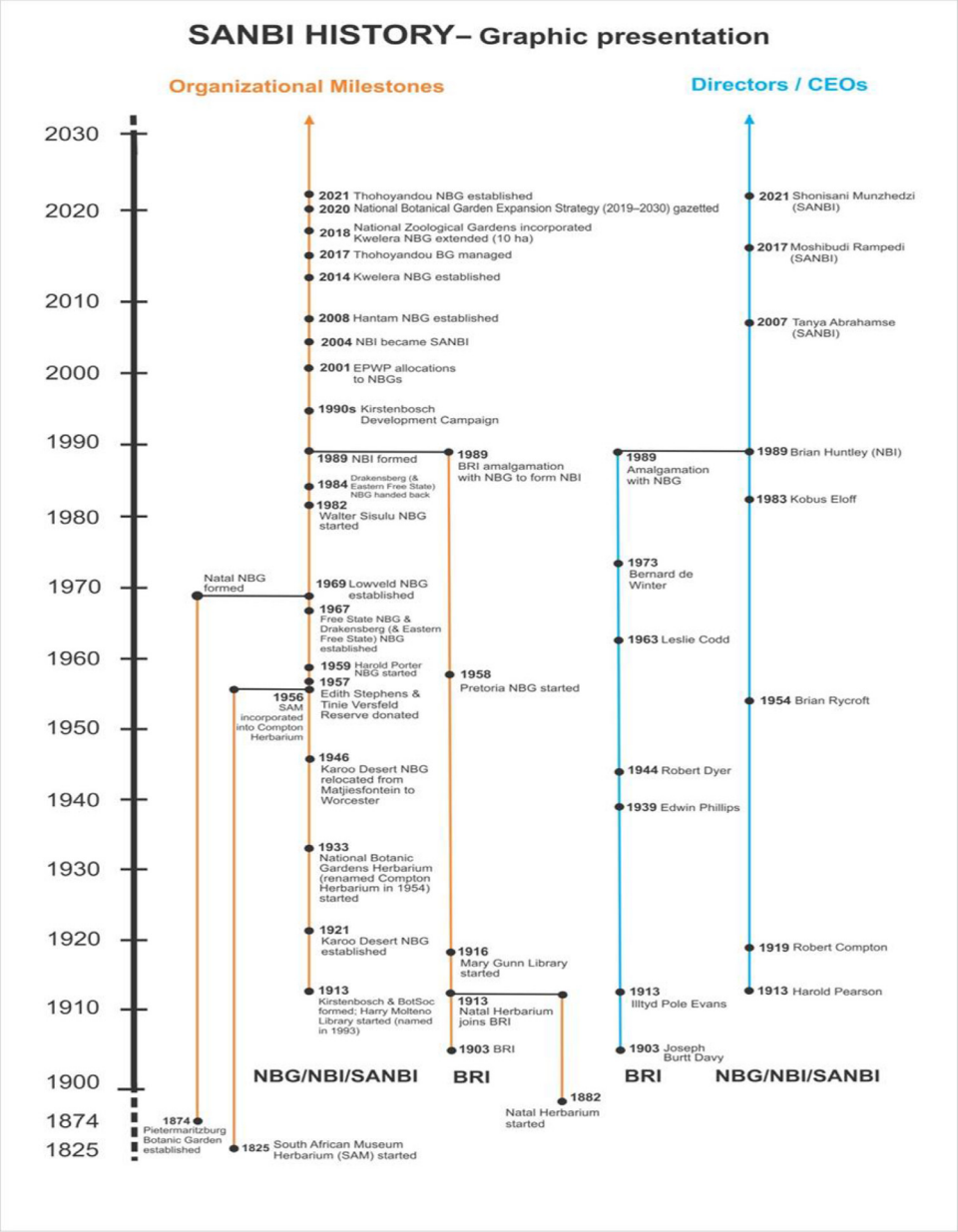

Fig. 1. Graphic representation of SANBI's history, highlighting organisational milestones and the Directors/CEOs who served to date.

use of indigenous biological resources. With this legislative mandate SANBI assumes the responsibility for safeguarding the nation's biodiversity assets, its constituent genetic material, including assessment of emerging threats to biodiversity and ecosystems. This role is pursued through scientific research, mobilization of biodiversity information, use of scientific findings to advance environmental awareness, promote sustainable use and conservation, and to inform decision and policy-making at a national, regional, and/or global levels. Globally, another organization with a similar mandate is the Commission for the Knowledge and Use of Biodiversity (CONABIO) - an Inter-Ministerial Commission in Mexico dedicated, among other activities, to the development, maintenance and update of the National Biodiversity Information System (SNIB); to the support of projects and studies focused on the knowledge and use of biodiversity; to advise governmental institutions and other sectors; to undertake special projects and programs and share knowledge on biological diversity; and to follow up on international agreements on topics related to biological diversity, and provide services to the public (CONABIO, 2017). Accordingly, SANBI like CONABIO, acts as the national scientific authority for CITES, the Focal Point of the Clearing House Mechanism (CHM), the Scientific advisory body (SBSTTA), The Global Taxonomy Initiative (GTI), and the Global Strategy for Plant Protection (GSPC) of the Convention on Biological Diversity.

Botanic gardens are considered 'windows to biodiversity' and are established primarily for purposes of display, educational/teaching, research and conservation, in alignment with the Botanical Gardens Conservation International's (BGCI) definition of botanical gardens (Wyse Jackson and Sutherland, 2000; Smith and Harvey-Brown, 2017). SANBI's national botanical gardens, in addition to more than twenty other botanical gardens across South Africa (Department of Forestry, Fisheries and Environment (DFFE), 2023a) that are managed at various levels ranging from private, university, to government (local, district, and provincial) excluding the nature reserves and parks, all contribute to a national conservation estate in South Africa. Being located largely in urban areas, SANBI's gardens are best placed to enable provision of specialized technical services such as

horticulture, and advisory services to several municipalities and provincial conservation authorities in their areas of jurisdiction.

The broadening of SANBI's legislative mandate through the NEMBA meant that the scope of SANBI work should cover all types of biodiversity – a goal that was fully realized in 2018 through the incorporation of the National Zoological Gardens (NZG) in Pretoria and its satellite campus in Limpopo Province (the Mokopane Biodiversity Conservation Centre, MBCC), then a National Research Facility under the National Research Foundation (NRF), into SANBI. SANBI has and continues to be at the centre of botanical research in South Africa (Smith et al., 2008; Victor et al., 2016), and over the years has successfully led and contributed to key national and regional programmes such as the Southern African Botanical Diversity Network (SABONET) (Huntley, 1998c) aimed at documenting botanical diversity and building related human capacity in South and southern Africa (targeting 10 countries of southern Africa namely Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland (now eSwatini), Zambia and Zimbabwe). This programme supported participating countries to be competent at inventory, monitoring, evaluation and conservation of the botanical diversity of the region in the face of specific developmental challenges, and to respond to the technical and scientific needs of the United Nations Convention on Biological Diversity (UNCBD, 2012). Reviews of the project concluded that SABONET under the administrative, logistical and strategic leadership of SANBI had been 'very successful in attaining its goals of building capacity through training, purchase of equipment, digitization of plant specimens preserved in herbaria, production of informative literature and creation of Red Lists for the participating national institutions (Siebert et al., 2001; Huntley et al., 2002). Other notable roles of SANBI in regional botanical leadership has been involvement in the African Plant Initiative (API) to digitize historical plant collections, particularly the type specimens that are important in taxonomic research and promote accessibility; and the Global Taxonomy Initiative (GTI) to address the lack of taxonomic information and expertise required to support the implementation of the UNCBD at all three levels of biodiversity (genetic, species, and ecosystem).

Nationally, SANBI led the development of an online electronic flora (e-Flora) of South Africa (Le Roux et al., 2017) as part of the global World Flora Online project, a global initiative in response to Target 1 of the Global Strategy for Plant Conservation (UNCBD, 2012) to compile a floristic inventory and taxonomic information of all known plants in the world (Paton, 2013; Miller et al., 2014). The leadership of SANBI was sought by the NRF for an entity to coordinate the implementation of the Foundational Biodiversity Information Programme (FBIP) with the aim to mobilize taxonomic information that is foundational to understand the occurrence, distribution, and threats to biodiversity in South Africa, as well as inform policy decision-making. The establishment of the South African Biodiversity Information Facility (SABIF) with funding from the Department of Science Technology and Innovation was in fulfilment of the legislative mandate for SANBI to "collect, generate, process, co-ordinate and disseminate information about biodiversity and the sustainable use of indigenous biological resources, and establish and maintain databases in this regard" (NEMBA, 2004). Through this programme (SABIF), which is currently affiliated with the Global Biodiversity Information Facility (GBIF) as a formal Country Node, SANBI is making good progress in mobilizing and sharing of species and specimen data and information (Coetzer et al., 2012; Parker-Allie, 2012). However, there are skills shortages in bioinformatics, and there is urgent need to develop biodiversity informatics competencies in South Africa (Parker-Allie et al., 2023). The recent announcement by the CBD Secretariat designating SANBI to serve as one of the sub-regional technical and scientific cooperation support centres (https://www.cbd.int/doc/notifications/2024/ntf-2024-058-tsc-en.pdf) is further acknowledgement and recognition of SANBI's institutional capacity to manage complex projects and programmes, mobilize and manage resources, and work with networks of collaborators.

Pursuit of strategic alliances and partnerships at national and international levels enables SANBI to execute its exceptionally broad legislative mandate with great efficiency (SANBI, 2018) by tapping into expertise resident elsewhere. The ability to tackle societal developmental challenges has increasingly become reliant on science-based solutions, and therefore knowledge-based organizations such as SANBI with its ability to mobilize, convene, and coordinate multi-disciplinary teams have become indispensable. SANBI has a proud history of plant taxonomic research (Killick, 1979; Smith et al., 2008; Victor et al., 2016; Victor, 2021). SANBI recognized climate change and biodiversity loss as some of humanity's greatest environmental risks, and over the years began to explore the interplay between biodiversity, climate change and environmental degradation (Midgley and Roberts, 2001; Bond et al., 2003; Huntley and Barnard, 2012) through focused research on the assessment of the impacts of climate change on biodiversity and ecosystems. However, the loss of capacity in this area led to a termination of the research program.

From the early beginning as Botanical Research Institute (BRI) to National Botanical Institute (NBI) and through to the establishment of SANBI, the quality, relevance and impact of its programmes including contribution to national government priorities such as job creation, poverty alleviation and skills development in the conservation and biodiversity sector have been highlighted and commended (Compton, 1965; Edwards, 1979; Killick, 1979; Wells, 1979; Willis and Huntley, 2001; Jossel and Donaldson, 2013). In the last fifty years SANBI underwent significant transformation in both its composition, services and product offering under no fewer than six Directors /Chief Executive Officers that steered the Institution to play a meaningful and impactful role in society. SANBI has had the courage to establish in-house publications such as *Bothalia, Memoirs of the Botanical Survey of South Africa, Flowering Plants of Africa*, and the *Flora of Southern Africa* which featured largely authoritative botanical research outputs of the Institute, and contributions by scientists from other institutions working on the flora of southern Africa (Edwards, 1979; Killick, 1979; Wells, 1979).

SANBI, in line with its mandate as per the NEMBA (2004) to "*... establish facilities for horticulture display, environmental education, visitor amenities and research; collect, generate, process, coordinate and disseminate information*" about biodiversity and the sustainable use of indigenous biological resources, runs two libraries, the Mary Gunn Library housed in the Pretoria National Botanical Garden and the Harry Molteno Library based at the Kirstenbosch National Botanical Garden. The two libraries have an estimated combined collections of over 19 200 books that cover various subjects such as taxonomy, morphology, plant anatomy, biogeography, ethnobotany, conservation, floras, ecology, history of botany, paleobotany. Since 2004 the library collections have grown to cover other subject matters such as biodiversity management, global change impacts, zoology, geographical information system, invasive species, etc. The Harry Molteno Library was started in 1913 as a 'garden library' in the Kirstenbosch National Botanical Garden to support the garden mandate of South Africa's first national botanical garden. This was made possible with funding sourced from the Molteno Trust with the condition that it be named after the Chairman of the Trust, Harry Molteno. On the other hand, the Mary Gunn Library was established in 1916, based at the Vredehuis in the Division of Botany under the Department of Agriculture of the Government of the Union of South Africa. This Library was later named as a dedication to its first Librarian, Ms Mary Gunn. Over the past century the two libraries have become valuable resources for information on the southern African flora and fauna, serving as repository for information on biodiversity, thus, meeting the information needs of SANBI staff and public demand for comprehensive, easily accessed information on the biodiversity of southern Africa. These libraries rank amongst the biggest botanical libraries in the

southern hemisphere. In addition to the acquisition of modern books and reference materials, the two Libraries are homes to some of the rarest books in the field of botany such as *Horti medici amstelodamensis (1697 – 1701)* by *Jan Commelin and Caspar Commelin, Plantae selectae (1750 – 1773) by C.J. Tre and illustrated by G.D. Ehret, Descriptiones plantarum ex capitae bonae spei (September 1767), Mandissa Plantarum (October 1767), Geraniologia (1787 – 1788) by C.L. L'Heritier de Brutelle* and plates by *P.-J. Redoute, The Botanist's repository (1797 – 1815) by H.C. Andrews, Redoutes Les Liliacees (1802 – 1816), Genera of South African Plants (1883) by W.H. Harvey*, generally considered the first scientific work published in South Africa. Since 2013 SANBI Libraries began a process to affiliate with the Biodiversity Heritage Library (BHL), a consortium of natural history and botanical libraries that work collaboratively to make biodiversity literature, especially the rare ones, openly available to the world as part of a global biodiversity community and to make literature freely available for responsible use as part of a global biodiversity commons.

SANBI is increasingly playing a catalytic role as an accredited entity under the Green Climate Fund (GCF) to oversee, supervise, manage and monitor the overall GCF-approved projects and programmes for implementation; and the recent appointment by the CBD Secretariat for SANBI to play a role of subregional scientific and technical cooperation centre in the SADC region highlights SANBI's standing nationally and internationally, thus becoming one of the five CBD centres in Africa and amongst the eighteen such centres globally. The aim in this review is to provide a historical account of SANBI and its role in advancing botanical research and knowledge on plant diversity in the past fifty years. SANBI's science capacity for botanical research and associated knowledge products such as peer reviewed articles are highlighted, including national government strategies that have shaped SANBI's programmes. Further, we highlight areas of pursuit and potential collaborations that have enormous potential to increase the level of engagement with society and further offer scientific and outreach expertise for SANBI.

2. Methodology

Data and information was sourced and analyzed from audited annual reports of SANBI (https://www.sanbi.org/about/annual-reports/sanbi-annual-reports-overview), other technical archival materials from SANBI libraries (Mary Gunn and Harry Molteno) and institutional data sets. Information on peer reviewed articles was accessed from https://opus.sanbi.org, and authorship was ascribed to SANBI when a SANBI's address was used as the author/co-author's affiliation on the article. Contributors to peer reviewed publications range from full time SANBI staff to interns, postdoctoral fellows, or collaborators from partner institutions. Only articles published in the ISI journals and those accredited by the Department of Higher Education were considered.

3. Results and discussion

3.1. Managing a network of national botanical gardens

Botanical gardens are defined internationally as 'institutions holding documented collections of living plants for the purposes of scientific research, conservation, display and education' (Wyse Jackson and Sutherland, 2000). Botanical gardens serve a unique role in conservation, and are defined by having the following characteristics: adequate labelling of the plants; an underlying scientific basis for the collections; communication of information to other gardens, institutions, organizations and the public; exchange of seeds or other materials with other botanical gardens, arboreta or research stations; long-term commitment to, and responsibility for, the maintenance of plant collections; maintenance of research programmes in plant taxonomy in associated herbaria; monitoring of the plants in the collection; open to the public; promoting conservation through extension and environmental education activities; proper documentation of the collections, including those of wild origin; and undertaking scientific or technical research on plants in the collections.

SANBI currently manages a network of eleven national botanical gardens spread across eight of South Africa's nine provinces (Fig. 2). South Africa's national botanical gardens, serving as windows to the richness of botanical diversity, culture and heritage, play key roles in the conservation, research, enjoyment and education of the public and learners through their displays, conservation and environmental education programmes (both within the gardens and in surrounding communities). These gardens serve as refugia for threatened plant species and serve an important role in promoting social cohesion and climate change adaptation particularly in South Africa's urban areas. One and a half million people make use of SANBI's national botanical gardens each year, offering an opportunity for gardens to provide information to visitors about biodiversity, conservation and sustainable use, as well as to promote the beauty of South Africa's indigenous plants and use of the gardens for personal/mental wellbeing. Horticultural and seed conservation research is conducted in the gardens, often in partnership with national (such as academic institutions, the Agricultural Research Council, South Africa) and international (Royal Botanic Gardens, Kew) partner organizations and researchers.

3.1.1. Gardens expansion strategy

The vision for a network of botanical gardens can probably be traced and attributed to the late Prof. Harold Pearson (1870–1916), the first Director of the National Botanic Gardens in South Africa, who once commented that "*a single botanic garden, however large or well-equipped, would not serve the whole of South Africa. Owing to geographic considerations it would be necessary to have at least ten National Botanic Gardens in South Africa, one in each of the main climatic regions, and that one (he suggested it be based on the Cape Peninsula) should be the administrative centre for them all*". The oldest of SANBI's botanical gardens (not the oldest national botanical garden) is the Pietermaritzburg Botanical Garden, having been established in 1874 in response to a need for seedling trees, particularly commercially viable timber and fruit trees in the Natal Midlands (Table 1). However, Kirstenbosch National Botanical Garden is of high significance as a model for shaping the conceptualization and development of other SANBI gardens given its unique natural features and setting. An interesting aspect to note is that the lay-out of Kirstenbosch followed no fixed plan. Compton (1965) in his book *Kirstenbosch, Garden for a Nation*, reflected as follows: "[The lay-out] *has gradually unfolded itself, as it were, in response to experience, to a realisation of what is necessary and what is possible, and to expanding ideas of the scope of its work. Each piece of construction involved a consideration of what could be done with the labour and funds available, and further, whether it would be possible to carry out the consequent additional maintenance*". He went on to reflect that "*the fact that the early years – not to say the whole history – of the Gardens were painfully cramped by lack of funds prevented undue haste with perhaps serious consequences. Mistakes were made, naturally enough, showing themselves and having to be corrected later; but it is quite likely that, in the special conditions at Kirstenbosch, a fixed design too rapidly carried out might have had worse results*."

Kirstenbosch National Botanical Garden was established in 1913, and various other national botanical gardens were established by SANBI (and its preceding organisations – National Botanic Gardens of South Africa, Botanical Research Institute and National Botanical Institute) over the past 112 years (Table 1). For most of the 20th century, the expansion of gardens was largely opportunistic, as land became available through support from national and provincial government, donations, bequests and sponsorships received from individuals, municipalities or NGOs, both national and international. In

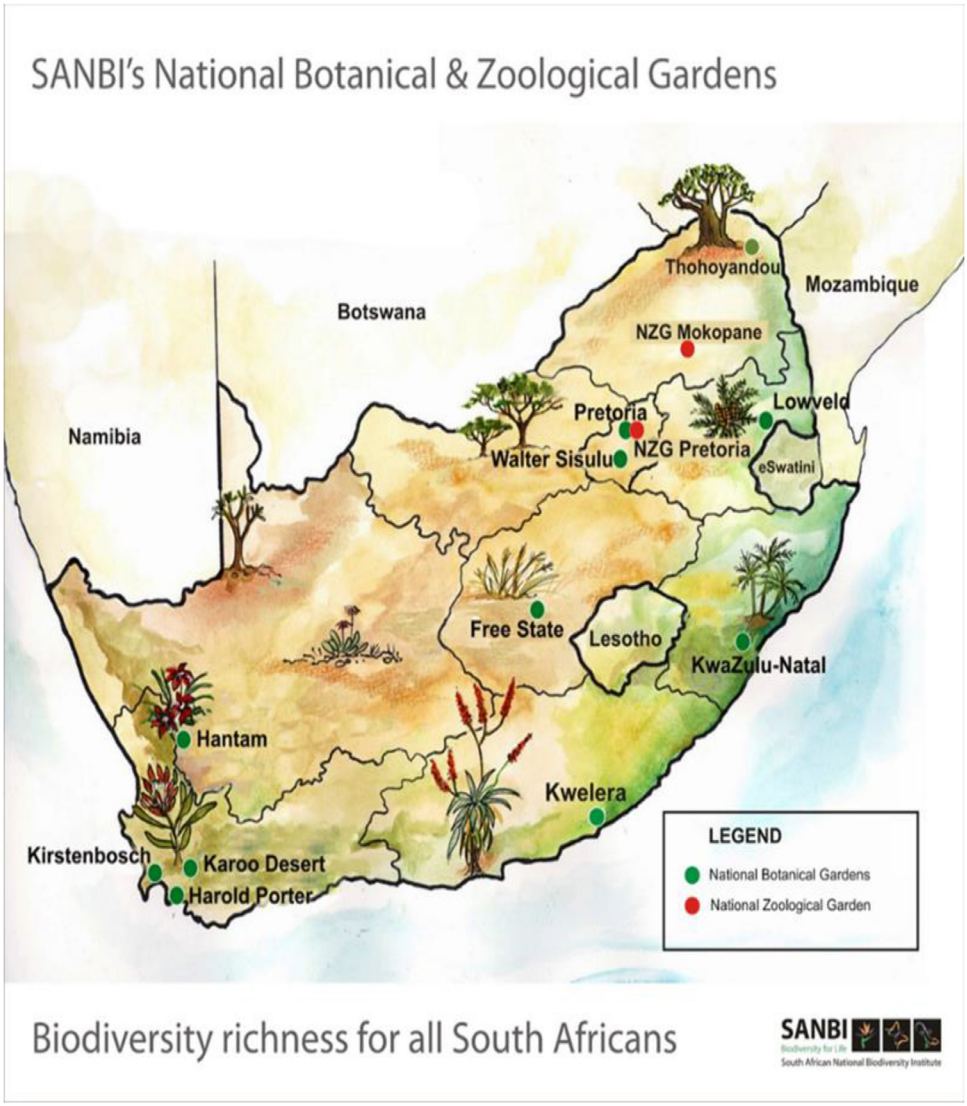

Fig. 2. Map depicting the distribution and occurrence of SANBI's gardens (botanical and zoological).

many cases the initial land portions of the gardens were expanded into strategically located adjacent land to enhance their conservation and aesthetic value. SANBI was visionary in its establishment of a network of national botanical gardens and is probably the only institution worldwide that manages such a large network of botanical gardens under a single organisation.

The Karoo Desert National Botanical Garden was founded in 1921, and up until the 1950s, the National Botanic Gardens had only two gardens under their control, both in the Western Cape. Another garden in the Western Cape, the Harold Porter NBG, was founded in 1959 following a bequest from the late Harold Porter (1883–1958). It was not until 1967, following Kirstenbosch's golden jubilee celebrations in 1963, that the National Botanic Gardens of South Africa extended its activities outside the then Cape Province. The purpose of this programme of expansion was (a) to provide sites where eventually the entire South African flora could be cultivated, and (b) to make botanical gardens accessible to as many people in the country as possible. To provide the maximum contribution to science it was considered that the various botanical gardens would, as far as possible, be situated near large educational centres or near areas of dense population. The next gardens to be founded were the Drakensberg and Eastern Free State (Harrismith, officially opened on 18 May 1967), Free State (Bloemfontein, 30 June 1967), KwaZulu-Natal (Pietermaritzburg, 12 November 1969), Lowveld (Nelspruit, 19 November 1969), and Walter Sisulu (Roodepoort/Mogale City, 11 March 1982) National Botanical Gardens. Lack of local support and remoteness unfortunately resulted in the Drakensberg and Eastern Free State Botanic Garden being handed back to the Harrismith Municipality in 1985.

By 1954, when Prof. Brian Rycroft (1918–1990) succeeded Prof. Harold Compton (1886–1979) as the third Director of the National Botanic Gardens, only Kirstenbosch and the Karoo National Botanical Garden had been established. During his term as Director, Prof. Rycroft was responsible for establishing the following five National Botanical Gardens that still exist today, namely Harold Porter, Free State, KwaZulu-Natal, Lowveld and the Walter Sisulu NBG. The Pretoria National Botanical Garden, officially opened in 1958, was managed by the former Botanical Research Institute (BRI) until amalgamation in 1989, when it was brought under the control of the newly formed National Botanical Institute (NBI), as South Africa's eighth national botanical garden. It was not until SANBI was established in 2004 that three new national botanical gardens – Hantam (2008) in the Northern Cape, Kwelera (2014) in the Eastern Cape and Thohoyandou (2021) in the Limpopo Province – were added to the network (Table 1).

In the mid- to late 2000s, SANBI started formalizing the expansion of botanical gardens (Willis and Huntley, 2004; Willis, 2010).

Table 1
Summary of the main features of South Africa's national botanical and zoological gardens.

Garden	Location, Province	Area (ha)	Date proclaimed	Biome/ecosystem types represented	Vegetation types represented (based on Mucina & Rutherford 2006)	Notes
Free State National Botanical Garden	Bloemfontein, Free State Province	67	1967	Grassland Nama Karoo Freshwater (river)	Gh 7 Winburg Grassy Shrubland Gh 8 Bloemfontein Karroid Shrubland Gh 5 Bloemfontein Dry Grassland	First NBG declared outside the then Cape Province. Following the transfer of a 41.08 ha portion of land, commonly known as Winters Valley, from the Bloemfontein Municipality to the National Botanic Gardens in 1967 when development started, an additional 25.7 ha portion of land was added to the northern boundary of the Garden. Garden's name changed from Orange Free State National Botanical Garden to Free State National Botanical Garden on 9 January 1998. The Garden has been declared as a National Monument (now Provincial Heritage Site), SAHRA Identifier 9/2/302/0039.
Hantam National Botanical Garden	Nieuwoudtville, Northern Cape	6,230	2008	Succulent Karoo Fynbos	FRd 1 Nieuwoudtville-Roggeveld Dolerite Renosterveld FRs 2 Nieuwoudtville Shale Renosterveld SKt 2 Hantam Karoo	Glenlyon Farm was purchased by SANBI from the late Neil MacGregor in 2007 as a representative area of the region's exceptionally rich natural bulb diversity unique to the Bokkeveld Plateau. Nieuwoudtville markets itself as the 'bulb capital of the world'.
Harold Porter National Botanical Garden	Betty's Bay, Western Cape	204	1959	Fynbos Forest Freshwater (rivers) Wetland Marine	FFd 6 Hangklip Sand Fynbos FFs 11 Kogelberg Sandstone Fynbos FOz 1 Southern Afro temperate Forest FS 7 Overberg Dune Strandveld	The initial land portions comprising 172 ha were bequeathed to the National Botanic Gardens of South Africa in 1959 by the late Harold Porter following his death in 1958. Various land portions were subsequently added to the estate, particularly south of Clarence Drive (R44). The Garden is unique in stretching from the Kogelberg mountains in the north down to the sea. The Garden also forms part of the Kogelberg Biosphere Reserve. The first biosphere reserve to be registered in South Africa in 1998, the Kogelberg Biosphere Reserve is considered to be the heart of the Cape Floral Kingdom – one of just six plant kingdoms in the world. The Garden consists of 10 hectares of cultivated fynbos and 194 hectares of pristine natural fynbos and Afro temperate forest.
Karoo Desert National Botanical Garden	Worcester, Western Cape	154	1921	Succulent Karoo Fynbos	FFh 4 Breede Shale Fynbos FRs 8 Breede Shale Renosterveld SKv 7 Robertson Karoo	Initially established in 1921 close to Whitehill Station near Matjiesfontein. The Garden was moved to its current site in Worcester in 1945. The Garden's name was officially changed from the Karoo National Botanical Garden to Karoo *Desert* National Botanical Garden on 7 December 2001 as one of the few true 'desert' gardens of the world.
Kirstenbosch National Botanical Garden	Cape Town, Western Cape	199	1913	Fynbos Forest Freshwater (rivers)	FFg 3 Peninsula Granite Fynbos FFh 5 Cape Winelands Shale Fynbos FFs 9 Peninsula Sandstone Fynbos FOz 1 Southern Afro temperate Forest	Kirstenbosch was established as South Africa's first national botanical garden on 1 July 1913. Kirstenbosch was included in UNESCO's Cape Floral Region World Heritage Site when established in 2004. Kirstenbosch was the first botanical garden worldwide to be part of a *natural* World Heritage Site. Other botanical gardens declared as *cultural* UNESCO World Heritage Sites include Royal Botanic Gardens, Kew, Singapore Botanic Garden and the Padua Botanical Garden.
Edith Stephens Wetland Park	Cape Town, Western Cape	3	1957	Fynbos Wetland	FFd 5 Cape Flats Sand Fynbos	Land donation to National Botanic Gardens in 1957 to be managed as a satellite reserve by Kirstenbosch NBG. Adjacent to a larger portion of land managed by the City of Cape Town.
Tinie Versfeld Wildflower Reserve	Darling, Western Cape	20	1957	Fynbos	FRg 2 Swartland Granite Renosterveld	Land donation to National Botanic Gardens in 1957 to be managed as a satellite reserve by Kirstenbosch NBG.
KwaZulu-Natal	Pietermaritzburg, KwaZulu-Natal	48	1874/1969	Savanna Freshwater (river)	SVs 4 Ngongoni Veld	Established in 1874, the KwaZulu-Natal Garden is the oldest of SANBI's botanical gardens (but not the oldest **national botanical garden**). The Garden was initially established in response to a need in the Natal Midlands for seedling trees—particularly commercially viable timber trees and fruit trees. On 3 March 1874 the City Council granted the land to the Pietermaritzburg Botanic Society. The objectives of the Botanical Society were as follows: (a) the growing of plants for distribution in the Colony and collecting of indigenous plants for exchange; (b) the growing of commercially viable vegetable products suitable for the upper and central districts of Natal, and (c) the accumulation of plants of value, beauty, and rarity in the Society's Garden. For years the Garden distributed thousands of young plants annually (mostly free of charge) to Government and public institutions, resulting in a meagre income to the Pietermaritzburg Botanic Society. The Garden's 300 m Plane Tree Avenue (*Platanus acerifolia*) known as Marriot's Lane

(*continued on next page*)

Table 1 (*Continued*)

Garden	Location, Province	Area (ha)	Date proclaimed	Biome/ecosystem types represented	Vegetation types represented (based on Mucina & Rutherford 2006)	Notes
						(35 m tall) that was planted in 1908 by Mr WE Marriot (Curator) has been declared as Champion Trees (No.16) *. This lane is a central landscape feature of the botanical garden. Another group of exceptionally large (59.1 m tall) Rose Gums (*Eucalyptus grandis*) in the Garden's Gum Tree Corner has also been declared Champion Trees (No.59). The Garden has also been declared as a National Monument (now Provincial Heritage Site), SAHRA Identifier 9/2/436/0063.
Kwelera National Botanical Garden	East London, Eastern Cape	171	2014/2018	Coastal Forest Grassland Albany Thicket Marine Wetland Estuarine	AT 9 Albany Coastal Belt FOz 6 Southern Coastal Forest	Initial 161 ha state land portion (Farm 782; Kwelera Nature Reserve, a portion of East London Coast Nature Reserve) co-managed with Eastern Cape Parks and Tourism Agency (ECPTA) through formal Memorandum of Agreement between SANBI, ECPTA and the provincial Department of Economic Development, Environmental Affairs and Tourism (DEDEAT) signed in 2012. An additional 10 ha land portion was purchased by SANBI and declared as an extension to the Garden in 2018.
Lowveld National Botanical Garden	Mbombela, Mpumalanga	164	1969	Savanna Freshwater (river)	SVl 9 Legogote Sour Bushveld SVl 10 Pretoriuskop Sour Bushveld	The subtropical Garden was established on land donated by the Nelspruit Municipality and H.L. Hall and Sons Limited and straddles the Crocodile River as it passes through Mbombela. The confluence of the Nels River with the Crocodile River is visible from the Garden. The Garden includes the spectacular Cascades Waterfalls along a section of the Crocodile River. Plants representative of African tropical rainforests and South African forests were planted in the Garden in the 1990s.
Pretoria National Botanical Garden	Pretoria, Gauteng	70	1958	Grassland Savanna	SVcb 6 Marikana Thornveld	Initially part of Botanical Research Institute (BRI). Brought together with other NBGs in 1989 as part of amalgamation of the National Botanic Gardens and Botanical Research Institute to form the National Botanical Institute (NBI) in 1989. NBI became SANBI in 2004. The Garden has been declared as a National Monument (now Provincial Heritage Site), SAHRA Identifier 9/2/258/0085.
Thohoyandou National Botanical Garden	Thohoyandou, Limpopo	82	2021	Savanna	SVcb 21 Soutpansberg Mountain Bushveld	Land managed through formal Memorandum of Agreement between SANBI, and the Limpopo Department of Economic Development, Environment and Tourism (LEDET) signed in 2016. Services Agreement between SANBI and LEDET signed in 2017. The Garden is included within the Vhembe Biosphere Reserve.
Walter Sisulu National Botanical Garden	Roodepoort/ Mogale City, Gauteng	296	1982	Savanna Grassland Forest Freshwater (river)	SVcb 9 Gold Reef Mountain Bushveld Gm 10 Egoli Granite Grassland FOz 2 Northern Afro temperate Forest	Name of 'Walter Sisulu National Botanical Garden', previously 'Witwatersrand National Botanic Garden' and 'Transvaal National Botanic Garden', was declared by Government Notice No. 310 of 12 March 2004, with effect from 16 March 2004. Includes additional land added in 2014 and 2023/24.
National Zoological Gardens	Pretoria, Gauteng	85	1899	Transformed land	Transformed land	Founded by J.W.B. Gunning in 1899. It became the official **National** Zoological Gardens in 1916. Brought under SANBI on 1 April 2018. A large landmark tree near the entrance of the Pretoria National Zoological Gardens (*Ficus macrophylla* (Moreton Bay fig) known as 'The Zoo Giant' has been declared as a Champion Tree (No.64).
Mokopane Biodiversity Conservation Centre	Mokopane, Limpopo	1,398	1979	Savanna	SVcb 20 Makhado Sweet Bushveld SVcb 23 Polokwane Plateau Bushveld	Mokopane Biodiversity Conservation Centre was established in 1979 and opened to the public in October 1981, as a satellite station of the National Zoological Gardens, Pretoria Zoo (NZG). Extended to current area in 1999. In 2004 the NZG was proclaimed as a National Facility. Brought under SANBI from 1 April 2018.

* **Champion trees** are individual trees and groups of trees declared as **Protected** under Section 12 of the National Forests Act of 1998 by the then Department of Agriculture, Forestry and Fisheries (DAFF), now the Department of Forestry, Fisheries and the Environment (DFFE).

Learning from its experience of managing botanical gardens in urban environments across South Africa since 1913, criteria for establishing new gardens were developed, and in South Africa's National Biodiversity Framework (NBF) published by the National (Department of Environmental Affairs (DEA), 2009) it was stated under Strategic Objective 5 (Protected areas and conservation areas) that SANBI should develop a National Botanical Gardens Expansion Strategy. Following a period of extensive consultation and review, South Africa's National Botanical Garden Expansion Strategy 2019 – 2030 (the 'Strategy') was formally gazetted by the Minister of the Department of Forestry, Fisheries and the Environment (DFFE) for implementation in December 2020. The aim of the Strategy is to have a national botanical garden represented in each of South Africa's nine provinces. Currently the only province without a national botanical garden is the North West Province. SANBI is working with DFFE and provincial conservation authorities, as well as other key stakeholders in the North West Province, to establish a new national botanical garden in the province by 2030.

In addition, all of South Africa's nine biomes should be represented in South Africa's network of national botanical gardens. When the Strategy was developed, only two biomes were not represented in the existing network, namely the Desert Biome and Indian Ocean Coastal Belt Biome. Instead of establishing new national botanical gardens in these two biomes, opportunities existed to partner and collaborate with existing government or parastatal agencies that manage protected conservation areas representative of these two biomes, more specifically the South African National Parks (SANParks) that manages the Richtersveld National Park in the Desert Biome, and either iSimangaliso Wetland Park, Eastern Cape Parks and Tourism Agency (ECPTA) or Ezemvelo KZN Wildlife, that all manage representative conservation estates in the Indian Ocean Coastal Belt that stretches from the Kei River in the Eastern Cape province northwards up to the Mozambique's southern border. Areas identified in these biomes would become botanical/demonstration gardens accessible to the public but not classified as national botanical gardens. SANBI would enter into a formal agreement with the institution hosting the area designated as a botanical/demonstration garden. In partnership with SANParks, the Richtersveld Desert Botanical Garden, showcasing and conserving the unique and threatened plants of the Desert Biome south of the Namibian border, was established as a 'demonstration garden' in the Senderlingsdrift section of the Richtersveld National Park and launched in 2024. According to the National Botanical Garden Expansion Strategy, opportunities exist to expand selected national botanical gardens into suitable adjacent natural habitats. The main purpose for such expansion would be for either (a) incorporation of additional unique and/or threatened species, vegetation types and habitats currently not represented into the Garden, (b) conserving adjacent habitats through integrated land use planning and/or available protection mechanisms to minimize impacts on the sense of place or conservation value of the Garden, or (c) incorporation of additional natural habitat that can serve as useful biodiversity and climate adaptation corridors for flora and fauna, both inside and outside the Garden. Opportunities may also exist to assist establish satellite gardens near existing botanical gardens in partnership with local communities. These satellite or outreach gardens are often established as a joint effort between SANBI's National Botanical Gardens Division and the Biodiversity Education and Public Engagement Directorate and form an important part of SANBI's outreach programme contributing to both horticulture and education skills development. The establishment and maintenance of strategic partnerships, with national and provincial conservation authorities, will be critical to SANBI's successful implementation of this Strategy.

3.1.2. Gardens of the Future

As SANBI continues to expand and consolidate its network of national botanical gardens, it is working towards a concept of 'Gardens of the Future'. This concept builds on the four key areas of what botanical gardens are designed for, namely research, conservation, tourism/display/visitor services and education (Wyse-Jackson and Sutherland, 2000; Wyse-Jackson, 2003). As we move deeper into the 21st century, the vision is that South Africa's national botanical gardens will increase their relevance to society, conservation and surrounding communities, and contribute towards job creation, skills and economic development (Willis, 2015). Other focus areas will include contributing towards key national and international goals such as the Sustainable Development Goals, become more resilient to climate change through development of landscape adaptation plans, implement SANBI's Green Energy and Water Conservation Strategy, SANBI's Infrastructure Master Plan 2023/24 to 2029/30 (SANBI, 2023) the NZG Repositioning Strategy and support the implementation of the Global Biodiversity Framework. SANBI will continue to strengthen its collaboration with Botanic Gardens Conservation International (BGCI) and other strategic partners, such as the Botanical Society of South Africa (with whom SANBI has had a close partnership since 1913) in the development of other botanical gardens across the African continent. Maximizing their commercial potential, while avoiding crass commercialization, will be important for their sustainability. The management model applied by Prof. Brian Huntley in the 1990s in ensuring Kirstenbosch National Botanical Garden freed itself from many years of financial constraints (Compton, 1965) and became commercially viable (Huntley, 1998a; 1998b; 2024) through the 'Kirstenbosch Development Campaign', will need to be continued in most other gardens.

3.2. Biodiversity collections and management

3.2.1. SANBI herbaria

SANBI manages a network of three national herbaria with a combined estimated collection of more than 2.2 million specimens, inclusive of more than 25 000 type specimens (Table 2) representing plant biodiversity covering Bryophyta, Pteridophyta, Gymnosperms, and Angiosperms at different morphological stages. The Pretoria National Herbarium (PRE) houses one of the largest Cryptogamic collections (liverworts, hornworts and mosses) in Africa (Mothogoane et al., 2015) and the wood collections, Xylarium, incorporated from the Council for Scientific and Industrial Research (CSIR) in 2016. These collections present both a challenge and opportunity for SANBI with regards to human capacity and skills required to curate such specialized collections. Plant anatomy work has long ceased at SANBI, although basic equipment such as microtomes, blades, etc., are available but remain largely unused due to lack of expertise. Partnership with the forest industry and academia is therefore required to build the desired capacity and skills base for SANBI to provide the much-needed services to the industry. While the NH and PRE collections are still arranged and organized according to the Englerian systems of classification, the entire collection (ca. 800 000 specimens) at NBG has, however, been re-organized following the new angiosperm phylogenetic classification system (Angiosperm Phylogeny Group (APG), 2016), a molecular-based system of plant taxonomy for flowering plants (angiosperms) in which families are organized alphabetically within orders.

Over the past decade SANBI has had significant growth, coverage and geographical representation of plant collections with almost over 200 000 plant specimens added, largely reflecting an active field-based work informed by priorities in the Biosystematics Research Strategy (Victor et al., 2013; Victor, 2021) such as taxa with less than five specimens in SANBI holdings and targeting under-collected areas with high plant species diversity. This remarkable growth in herbarium specimens was achieved largely at NBG and PRE through participation in the Karoo BioGaps project in 2016 and the Waterberg Biodiversity project in 2022, both of which aimed to gather data on the occurrence and distribution of biodiversity (flora

Table 2
Summary of biodiversity collections (herbaria and biobanks) managed by SANBI.

Collection	Acronym*	Year Established	Collections					Notes
			Total specimens	No. Type Specimens	Taxonomic Coverage	Geography	Date of oldest specimens	
Compton Herbarium	NBG	1933	ca. 800,000	9,628	Higher plants, Pteridophytes	Cape Floristic Region	1825	The Compton Herbarium is the most comprehensive archival record of the winter rainfall region and is the second largest herbarium in South Africa. It includes the South African Museum Herbarium (SAM), the oldest in Africa and one of the oldest in the southern hemisphere. The first collection in the country to be completely re-organized according to a modern phylogenetic sequence.
KwaZulu-Natal Herbarium	NH	1882	ca. 127,320	ca.1,380	Higher plants, Pteridophytes	Eastern seaboard region of South Africa	1847	The KwaZulu-Natal Herbarium is the centre for the study of indigenous plants of the eastern region of South Africa. The collection is housed in a building that has a National Monument status.
Pretoria National Herbarium	PRE	1903	ca. 1,300,000	ca. 14,000	Angiosperms, Gymnosperms, Cryptogams (mosses and liverworts), Lichens, and a Xylarium	sub-Sahara region, with more than 70 % from the southern African region.	1811	The largest herbarium in South Africa and second largest in the southern hemisphere. The bulk of the collection consists of angiosperms and gymnosperms, with a fair representation of cryptogams (mosses and liverworts) (over 70,000), Lichens (use ca. 20,000) and a Xylarium (use ca. 5,000). Most of the collection data for FSA specimens captured on a specimen database.
Wild Plant Seed Bank	MSBP	1999	ca. 6,637	N/A	Angiosperms, Gymnosperms	South and southern Africa	1955	Mainly wild plant seeds and fruits
Wildlife Biobank	N/A	1994	ca. 250,000	N/A	Marine/fresh water and terrestrial vertebrates and invertebrates	South Africa, as well as various taxa representing 46 different countries around the world	N/A	Live cell culture collection representing critically endangered, extinct in the wild, and extinct mammal species.

* Thiers, B. (continuously updated) where applicable, N/A – not applicable or information not readily available

and fauna). The implementation of a national project, the Natural Science Collections Facility within the framework of the South African Research Infrastructure Roadmap (SARIR) of the DSTI, targeting large collections holdings in the public domain has highlighted the strengths and weaknesses within the three SANBI herbaria (NBG, NH, and PRE) through a self-assessment tool meant to improve management of the collections in compliance with the Collection Management and Conservation Manual (Natural Science Collections Facility, 2021). SANBI herbaria have since incorporated the recommendations of the self-assessment report to improve its policies related to data, acquisitions, health and safety in the collections space, and dealing with agents of collections deterioration / loss (i.e., fire, water, light, temperature, humidity, contaminants, security, custodial neglect, physical forces, pests).

3.2.2. Seed collections

Estimates are that nearly a quarter of the more than 23 500 plant taxa occurring in South Africa are considered either threatened with extinction or are of conservation concern (SANBI, 2024). Seed banks and storage can and have the potential to mitigate against the risk of species going extinct in the wild by acting as propagule material and diaspores for restoring ecological functions lost with a species' extinction, through replacement with a living, functionally equivalent organism (Rocchetti et al., 2022), and used as some form of an 'insurance' in the event a species extinction occurs. In view of this threat to South Africa's plant diversity, a special programme on wild plant seed collection began in earnest in 2000 through a partnership between SANBI and the Royal Botanic Gardens, Kew to participate in and contribute to a global Millenium Seed Bank Partnership (MSBP) that has to date collected more than 2.4 billion seed accessions worldwide covering some 40 000 plant species, 6 100 genera in 394 families (Liu et al., 2020). About 7 % of these global seed collections belong to South Africa, with an estimated 20 % of South Africa's flora being banked. The largest proportion of South Africa's plant families that have been secured in the seed bank include the Asteraceae, Fabaceae, Aizoaceae, Iridaceae, Ericaceae, Poaceae, Scrophulariaceae, Apocynaceae, Asphodelaceae, and Orchidaceae (Fig. 3) with 6 637 seed accessions collected and stored, and these represent 4 611 taxa for which restoration and conservation efforts on critically endangered taxa are possible. The 'outstanding gap' in Fig. 3 reflects the substantial diversity and taxonomic composition of South Africa's megadiverse flora. This calls for a dedicated effort to address the current acute skills shortage in taxonomy, and to develop the requisite human technical capacity and competencies (Smith et al., 2008; Victor et al., 2015) to develop and sustain a national programme on taxonomy that will have seed conservation as one of its components.

Through this effort, SANBI has made a significant contribution towards South Africa's attainment of Target 8 of the Global Strategy for Plant Conservation (Raimondo et al., 2009; Raimondo, 2015; von Staden and Raimondo, 2015; Teixido et al., 2017; Sharrock, 2020) which is one of the obligations under the Global Biodiversity Framework of the United Nations Convention on Biological Diversity (UNCBD). With the seed storage programme SANBI aims to develop and maintain a national *ex situ* seed collection of South Africa through development of a seed research and storage facility (seed bank), properly resourced and running to recognized international Seed Conservation Standards, that will be available as a national and international resource; ensuring that all South African indigenous threatened species are secured in long-term *ex situ* collections, and that all South African plant genera are represented in the seed bank. In essence, through this partnership and programme, South Africa has begun an important journey of mitigating against threats to plants in the wild by developing a national Wild Plants Seed Collection of South Africa that focusses on endangered species in the categories following the IUCN Red List categories (IUCN, 2025): CR, CRPE, EN, VU, EX, EW, threatened habitats and ecosystems, endemic taxa in

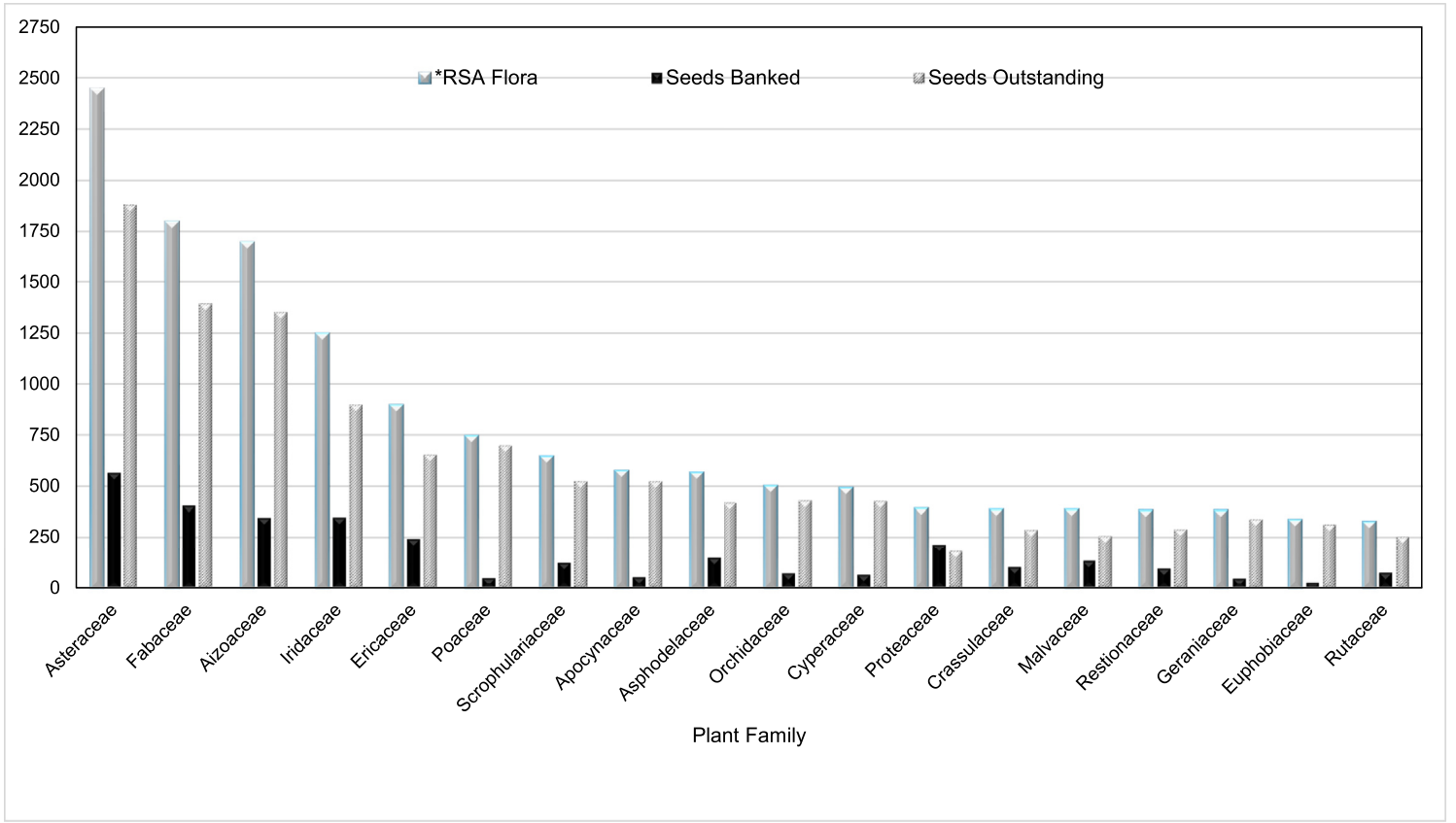

Fig. 3. Proportion of South Africa's plant families and genera represented in the Seedbank.

biodiversity hotspots, and species of economic importance such as crop wild relatives, medicinal plants and other useful plant species. The incorporation of the National Zoological Gardens into SANBI in 2018 provided SANBI with capacity for expanding its biodiversity collections to cover wildlife biomaterial (i.e. samples of animal tissues, skin, hair, blood, etc.), the largest and most comprehensive in the sub-Saharan Africa with over 250 000 samples (and growing) representing at least 76 000 individuals banked from room temperature down to minus 196 °C. Efforts are being made to extend and expand this research infrastructure (originally focussed on animal materials) to accommodate plant DNA extractions and sequencing needs to usher in a new era of molecular based systematics and taxonomic research at SANBI.

3.2.3. Biodiversity Information

Biodiversity informatics, which refers to the capture, cleaning, management, improvement, analysis and interpretation (Townsend Peterson et al., 2010) and involves human-computer interface and the development of appropriate software, has emerged and developed with advances in computational tools and information technology (Soberon and Townsend Peterson, 2004; Chapman, 2005; Sarkar, 2009). The capturing of herbarium specimen information in electronic form through digitization to allow for easy and rapid information retrieval has been at the core of SANBI's functions. In the 1970s SANBI spearheaded the development of a computerized botanical database, the National Herbarium (PRE) Computerized Information System (PRECIS) that became the largest botanical database in Africa with information on indigenous and naturalized plants in the Flora of southern Africa region (Mothogoane et al., 2015). As with any digital technology, it is important to retain the requisite skills and keep abreast of technological developments and innovations to remain relevant to modern needs. The lack of, and/or limited, in-house skills in this area of work at SANBI led to eventual migration of PRECIS to a modern globally accepted database, the Botanical Research and Herbarium Management System (BRAHMS) developed and maintained by the University of Oxford. SANBI's botanical information is made accessible to the wider public through the BRAHMS, and SPECIFY platform for animal species data, both of which provide information on specimens' occurrence and species descriptions that aid in identification. Since 2022 SANBI has, through the support of Bioshare Digitization company in Finland, installed a Conveyor Belt System for Mass Digitization of herbarium specimens. With an estimated 2.2 million herbarium specimens across the three SANBI herbaria (NBG, NH, and PRE) the entire collection will be digitized in just under five years using the conveyor belt system, which is a substantial improvement from the previous rate of 21 000 specimens digitized per annum that would take over 100 years to complete. This effort to digitize all herbarium specimens would expedite the capture, dissemination and publication of biodiversity data via the internet, for scientific discovery and sustainable development outcomes. While the API project focused mainly on digitizing the specimens of historical significance such as type specimens, the current mass digitization project aims to capture the entire SANBI collections in digital form. Concomitant with this effort to digitize the entire SANBI collections, is the need to invest in modern electronic storage capacity and related infrastructure such as cloud-based storage solutions.

3.2.4. Living collections

SANBI is amongst the institutions in South Africa holding a wealth of living collections located in the botanical and zoological gardens, and these are used by scientists for cutting-edge research and include both marine and terrestrial plants and animals. Within these collections are plants and animals of high conservation value and represent the flora and fauna from different habitats and biomes that contribute to distinctive landscapes across South Africa. In an effort to provide effective management of living collections in south Africa, SANBI with financial support from the DSTI coordinates a network of custodians of Living Collections within the biodiversity and conservation, agriculture, and higher education and training (academic) sectors in South Africa to ensure that the living collections are well-managed and curated, and are accessible to the scientific community; and to determine their sustainability and use for multi-and trans-disciplinary research. The Living Collections cluster is part of an ambitious National Scientific Research Collections Platform (NSRCP) of the DSTI (DST, 2016) and is aligned with the objectives of the Science, Technology and Innovation Decadal Plan 2022–2032 (DSTI, 2022). The purpose of the NSRCP is to provide strategic guidance and financial resources to facilitate a coordinated structure for the management of scientific collections (i.e. biodiversity biobanks, including gene and tissue banks, seeds, cuttings, eggs and sperm, veterinary samples; microbial culture collections such as bacteria, fungi, algae; medical biobanks focused on human biological materials; the natural science collections of preserved plants and animals, tissues and DNA extracts associated with specimens, fossils, geology; and the anthropology collections covering archaeology, cultural anthropology, and paleoanthropology) in South Africa and ensure that scientific research collections are accessible and used for quality and competitive research. The specific objectives of the NSRCP are to ensure long-term security and access to collections and associated data through the development and implementation of common policies, standards and collection strategies, development of human capacity for research, curation and data management, and development of research infrastructure; and to catalyze ground-breaking interdisciplinary research that relies on access to scientific collections and that addresses questions of relevance to South African society. Through this scientific research collections platform, SANBI is poised to explore and drive opportunities for enhancing economic potential of knowledge and products generated through collections-based research.

3.3. Research efforts

3.3.1. Research programmes at SANBI over the years

The body of SANBI's core programme of work can be summarized and categorized broadly into four main areas, notably the Foundational Biodiversity Science, the Biodiversity Planning, Biodiversity Mainstreaming into Sectoral Plans, and Policy Advice and Implementation. These programmes have evolved over several decades reflecting major organisational milestones from the early beginnings of Botanical Research Institute (BRI) in 1903, to the establishment ten years later of the Kirstenbosch National Botanical Garden (NBG) and other gardens that existed side by side with the BRI until amalgamation in 1989 to establish the National Botanical Institute (NBI), that became SANBI fifteen years later. The foundational biodiversity science work has since SANBI's inception been about plants – collections and inventories, species identifications, taxonomy, classifications, and mapping (Smith et al., 2008; Victor et al., 2016). Field collections to various regions of South Africa allowed for horticultural, taxonomic and systematics research to be an integral part of SANBI's core work, with the botanical gardens serving to display and disseminate information about the rich diversity of the South African flora. A synthesis of SANBI's horticultural research over many years since Kirstenbosch was established in 1913 is presented in Smith et al. (1999), Willis (2015; 2025) with notable achievements being breaking seed dormancy in a number of species of the fynbos family Restionaceae through development and use of effective plant-derived smoke, the development of a yellow-flowered cultivar of *Strelitzia reginae*, 'Mandela's Gold', named in honour of the late South African State President Nelson Mandela, and the establishment of seed orchards (gene banks) for South African cycads. The SANBI's Horticultural Conservation and Research Strategy developed in recent years is aimed at promoting conservation that is informed by scientific research principles to fulfill the SANBI mandate as expressed in

NEMBA and international treaties that South Africa has ratified, such as the Convention on Biological Diversity (CBD). This strategy has five objectives designed to meet the set strategic priorities and aims. These include Horticultural Research, Plant Conservation, Collaborations, Human Capital Development and Disseminate Plant Knowledge. SANBI's Horticultural Enrichment Forum (HEF) continues to provide horticultural leadership and enabling documentation and reports across SANBI's national botanical gardens, and encourage support, mentorship and coordination within conservation horticulture. In the Horticultural Conservation and Research Strategy, SANBI's horticulturists, coordinated through the HEF within the National Botanical Gardens Division of SANBI, have prioritized key conservation aspects that will have significant conservation impact and outcomes, in collaboration with other SANBI divisions, national, provincial, local stakeholders and authorities. Guided by this strategy, SANBI and its horticultural conservation teams continue to work closely with regional and international institutions and partners, such as the Royal Botanic Gardens (Kew, UK), Morton Arboretum (USA) and its Arboretum Accreditation Programme, the Missouri Botanical Garden (USA), the National Botanic Gardens of Ireland, BGCI (including representation on their International Advisory Council), the International Association of Botanic Gardens (IABG), the African Botanic Gardens Network (through BGCI) and the Climate Change Alliance of Botanic Gardens (CCABG), as a founding member. This area of work holds great commercial potential and can contribute to future financial sustainability, thus freeing SANBI from high dependency on the ever-shrinking national funding that must service an increasing number of national development priorities.

The *Flora of Southern Africa* is a historical project of SANBI established during the BRI era and maintained through and beyond NBI formation and was built on the strengths of *Flora Capensis* that documented the flora of colonial South Africa (Harvey and Sonder, 1860; Goldblatt, 1978). Since its establishment in 1955 the *Flora of Southern Africa* project covering five countries South Africa, Botswana, Lesotho, Swaziland and Namibia, however, remains incomplete seven decades later. For the past four decades the *Flora of Southern Africa* project has been pursued through regional treatments to achieve the same objectives (Rourke, 1999; Victor et al., 2015), and these regional floras have been delineated following largely the provincial boundaries of the Republic of South Africa since its democratic dispensation, with a few exceptions, and are published in-house by SANBI (Table 3) in the *Strelitzia* series. Some of the seminal works in the *Strelitzia* monograph series include works on grasses of southern Africa (Fish et al., 2015), botanical inventory of the Pondoland Centre of Endemism (Grieve et al., 2024), the flowering plant families of southern Africa (Koekemoer et al., 2015; 2023), on the vegetation map and field atlas of continental South Africa, Lesotho and Swaziland (Mucina and Rutherford, 2006; Mucina et al., 2014), and plants of the northern provinces (Retief and Herman, 1997). To date, regional flora have been published for the Free State province (Retief and Meyer, 2017), Eastern Cape province (Bredenkamp, 2019), the Core Cape Flora covering Western Cape and some parts of Northern Cape province (Manning and Goldblatt, 2012; Freiber and Manning, 2013), and the northern provinces or the former Transvaal region covering Gauteng, North West, Limpopo, and Mpumalanga (Retief and Herman, 1997). For KwaZulu-Natal flora, Volume 1 covering mainly the monocotyledons has been submitted for editing and should be available by end of 2025 (Singh, *pers comm*). The compilation of these regional flora has not been without challenges and there have been long delays in meeting the publication targets. The editors of these works depend largely on voluntary contributions and goodwill by taxon specific experts to provide inputs and in many cases, these are considered added responsibilities that often compete with full time employment contracts of contributors.

The biodiversity planning component of SANBI's work is formalized through NEMBA, wherein SANBI is expected to *"…advise the Minister on any matter regulated in terms of the Act on …conservation and sustainable use, including listed ecosystems; international agreements, biodiversity planning (bioregions, bioregional plans), declaration and management of, and development in, national protected areas"*. Accordingly, since 2004 SANBI has built the necessary capacity to play a critical role in convening communities of practice at provincial level to tackle issues on best management practices to deal with alien and invasive species, and coping strategies on adaptations to climate induced risks. SANBI has and continues to lead in the development of tools and guidelines meant to mainstream biodiversity into other sectoral development plans. To date, these guidelines cover the major areas of economic activity in South Africa, notably Agriculture, Mining, Land-Use Planning and Development. Key stakeholders in these areas (i.e. farmers – both smallholders and subsistence and largescale through their various commodity groupings on livestock and crops, mining houses and plant managers, and town planners and practitioners) are incorporating biodiversity and conservation priorities in their sectoral operational plans, thus avoiding irreparable damage to biodiversity and ecological infrastructure. An emerging body of work as per the NEMBA involves biological invasions and protection of biodiversity in South Africa (Preston and Siegfried, 1995; Shackleton and Gwedla, 2021; Zengeya and Wilson, 2023) with a focus beyond SANBI's national botanical gardens (Shackleton et al., 2011; Wilson et al., 2018; Mokotjomela et al., 2023; Wilson and Kumschick, 2024).

Section 60 of NEMBA (Act 10 of 2004) provides for the establishment of an independent organ of state, the Scientific Authority, with administrative, logistical, scientific and technical support from SANBI. The execution of this mandate has enabled SANBI to pull together expertise resident in other organizations through collaborative partnerships to provide advice to the Minister of Forestry, Fisheries and the Environment on all matters related to indigenous species on international trade as per the convention on international trade on endangered species (CITES) and the threatened or protected species (TOPS) by issuing non-detrimental findings on potential impacts of harvesting practices on species in the wild. In addition, collaborations with strategic partner institutions enable SANBI to develop key knowledge products such as National Biodiversity Assessment (NBA) report, Status Report on Alien and Invasive Species, status Report on Genetically Modified Organisms (GMOs) released into the environment, Threatened Ecosystems, Species Red Lists, Red List of Ecosystems (RLE), all geared to inform policy and decision-making.

3.3.2. Research capacity and outputs

For the first ten years since 2004, the achievements and impacts of SANBI's scientific work have been highlighted in a special publication, *SANBI: A Decade of Science 2004–2013* (Jossel and Donaldson, 2013) in which SANBI was profiled as a leader of biodiversity science in South Africa, reflecting on the standing and recognition of SANBI's science work nationally and internationally and the consolidation of science within SANBI, thus leading to an increasing impact of SANBI's scientific products. This positive trend and trajectory have been maintained in the last ten years and often exceeded (Fig. 4).

The introduction and implementation of a Career Ladder programmes for Horticulturalists (Willis et al., 2017), and in particular for Scientists in 2013 enabled and encouraged SANBI scientists to remain in research and pursue their careers without the burden of staff management responsibilities often associated with careers in non-science areas of operations. In the first year of its implementation (2013) a total of 36 scientists were registered on the programme occupying various levels from candidate scientists at the entrance level, mainly with an honours degree through to the more established senior and principal scientists with doctoral degrees and several outputs on knowledge generation and dissemination, collaboration and funding, biodiversity policy, planning and management, generating impact, and human capital development. The career ladder programme for scientists is not designed for assessment of

Table 3
SANBI's in-house publications.

Publication	Year Established	Aim	Scope (and selected examples where relevant)
Flowering Plants of Africa	1921	To stimulate an interest in the study, conservation and cultivation of African plants, and advance the science of botany and botanical art.	• A peer-reviewed publication of color plates with accompanying text and images of African plant species. It is a biannual journal with the Department of Higher Education (DHET) accreditation status.
African Biodiversity Conservation (ABC), formerly Bothalia	1922	To disseminate, to a wide audience, knowledge, information and innovative approaches promote and enhance the wise use and management of biodiversity in order to sustain the systems and species that support and benefit the people of Africa.	• Historical focus was on plant taxonomy and ecological research. The scope was widened in 2013 to include other elements of biodiversity in line with the expanded mandate of SANBI.
Strelitzia Series	1994	This series publishes original, peer-reviewed scientific research on various aspects of botanical diversity.	• No. 48: A systematic account of *Haemanthus* (Amaryllidaceae: Haemantheae) • No. 47: Botanical bounty of the Pondoland Centre of Endemism • No. 46: Flowering plant families of southern Africa • No. 45: A taxonomic revision of the genus Zyrphelis (Asteraceae, Astereae) in South Africa • No. 44: Photographic guide to the wildflowers of the Limpopo Province • No. 43: A monograph on the genus *Cliffortia* • No. 42: Iridaceae of southern Africa • No. 36: Identification guide to the southern African grasses. An identification manual with keys, descriptions and distributions
Biodiversity Series	2006	To publish occasional reports on projects, technologies, workshops, symposia and other activities initiated by, or executed in partnership with, SANBI	• No. 31: Early botanical exploration in the Kaokoveld (northwestern Namibia) 1957 • No. 30: Research plan for plant taxonomy 2020–2030 • No. 29: Guidelines for collecting living plant specimens from the field • No. 27: Gardens for the nation: 1994–2014. Serving and supporting South Africa's social and economic development for 20 years
Suricata Series	2014	To publish original, peer-reviewed scientific research on various aspects of zoological diversity.	• No. 11: Big bees of South Africa – A photographic identification guide to species • No. 9: A taxonomic monograph of the sea cucumbers of southern Africa (Echinodermata: Holothuroidea) • No. 8: Manual of Afrotropical Diptera. Volume 3. Brachycera–Cyclorrhapha, excluding Calyptratae • No. 7: Cicadas of southern Africa. An illustrated guide to known species
Ad-hoc publications	2006	For publications with botanical or zoological subject matter not accommodated in the SANBI monograph series of Strelitzia, Suricata or Biodiversity Series.	• Guide to the identification of succulent plant species included by South Africa in Appendix III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) • South African animals at risk of extinction • Ecosystem Guidelines for the Savanna Biome • National Biodiversity Assessment 2018: The status of South Africa's ecosystems and biodiversity. Synthesis Report • The Status of Biological Invasions and their Management in South Africa Report • SANBI Annual Report

employees' performance at their job on an annual basis; rather, it is a set of criteria to define different ranks gauged over multi-year periods. This programme has proved useful in attracting and also retaining talented scientists within SANBI and was bolstered by the implementation of SANBI's Sustainable Transformation Charter from 2021 that aims to transform the profile of the research cohort and ensure representativity in terms of race and gender in the recruitment and eventually the authorship profile of SANBI publications. The career ladder programme for scientists at SANBI enabled an effective and more objective performance management of researchers and their knowledge outputs and services. Over the past ten years SANBI experienced a steady increase in the number of researchers with improved academic qualifications, and this correlates with an increase in publication outputs (Fig. 4) that are split more or less equally between the foundational biodiversity science work (i.e. taxonomy, systematics, mapping and distribution patterns, etc.) to the development of knowledge tools for biodiversity planning (i.e. species, populations and ecosystems assessments, status, trends monitoring and modelling). For the five years ending 2024, SANBI achieved an overall 648 peer reviewed publications in international scientific indexing (ISI) journals, reflecting an average of 130 publications per annum (Fig. 4). Overall, there has been a steady increase in peer-reviewed publications since 2020 with a noticeable growth in contributions to ISI rated journals during the COVID-19 lockdown, a time when access to research facilities was severely curtailed. It is possible that the restrictions in movement afforded scientists the time to work on research data accumulated over the years, thus leading to a spike in publications. Publications were spread across a range of journals of varying impact factors, and analysis reveals that 72.2 % of the publications were in journals with an impact factor of < 1.9, followed by 23.4 % publications in journals with impact factor between 2 and 5, then 3.4 % of the publications in journals and between 5.1 and 10, and only 1 % were in highly ranked prestigious journals with an impact factor >10 such as Trends in Ecology, Science and Nature. The incorporation of the NZG into SANBI brought additional research team and capacity from the NZG whose publication record was relatively high. However, the drop in publications in the last two years is attributable largely to loss of key personnel through either resignations or retirements and a long lag-phase from recruitment to optimal productive level of new incumbents, particularly those entering the research career ladder at the bottom. Analysis of the age (Fig. 5) and population group (Fig. 6) profiles of SANBI publications authorship for the past five years indicates that most authors were in the age category 36 to 45 years, with those under 35 years old peaking in the 2022/23 period, then dropped significantly to half. The middle-aged authors' (i.e. 45 to 55 years old) contributions fluctuated in the range of 13 to 16 authors for same period. Authorship by population groups for same period reflected historical (South

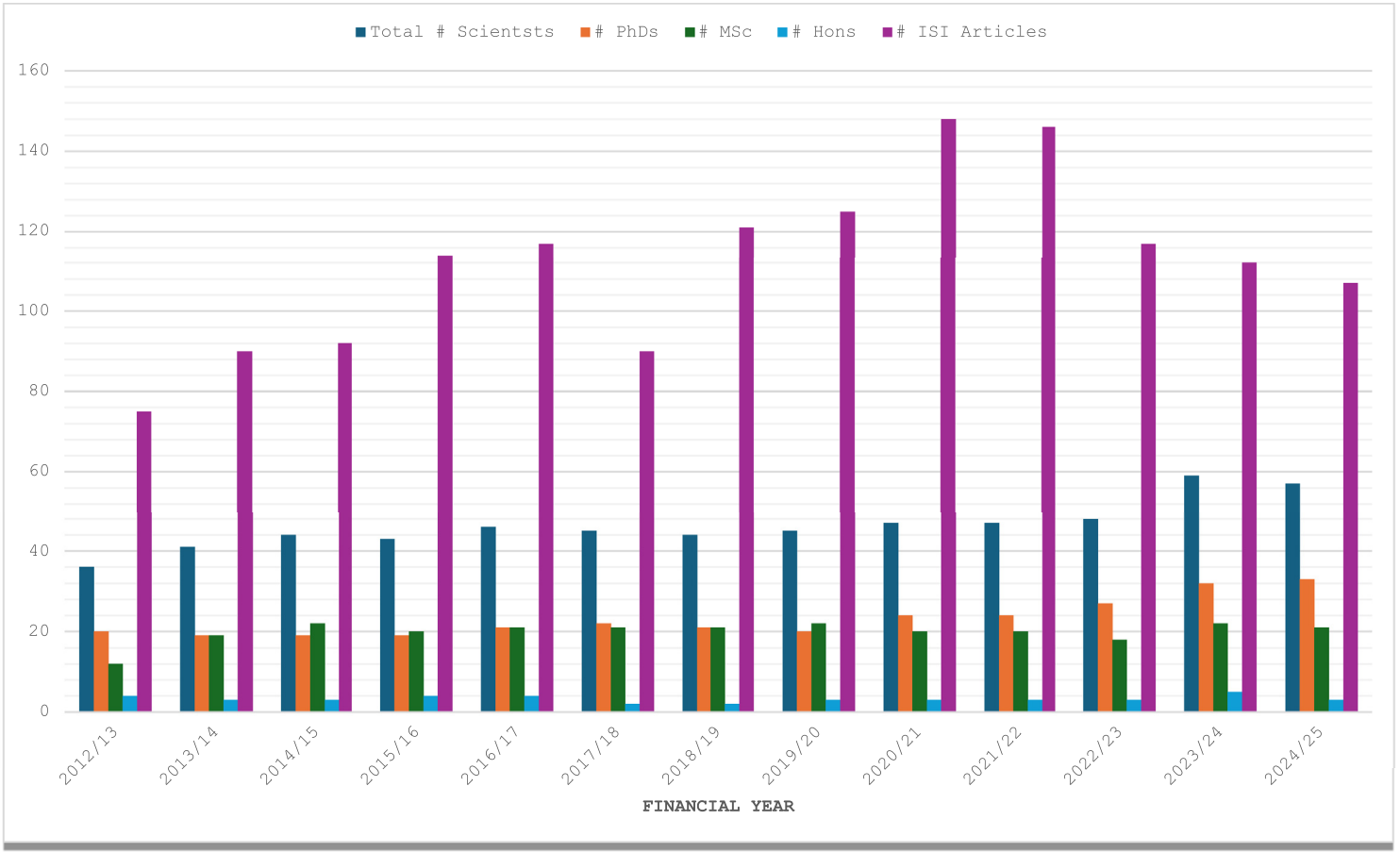

Fig. 4. SANBI's research capacity and outputs through peer-reviewed articles in ISI journals.

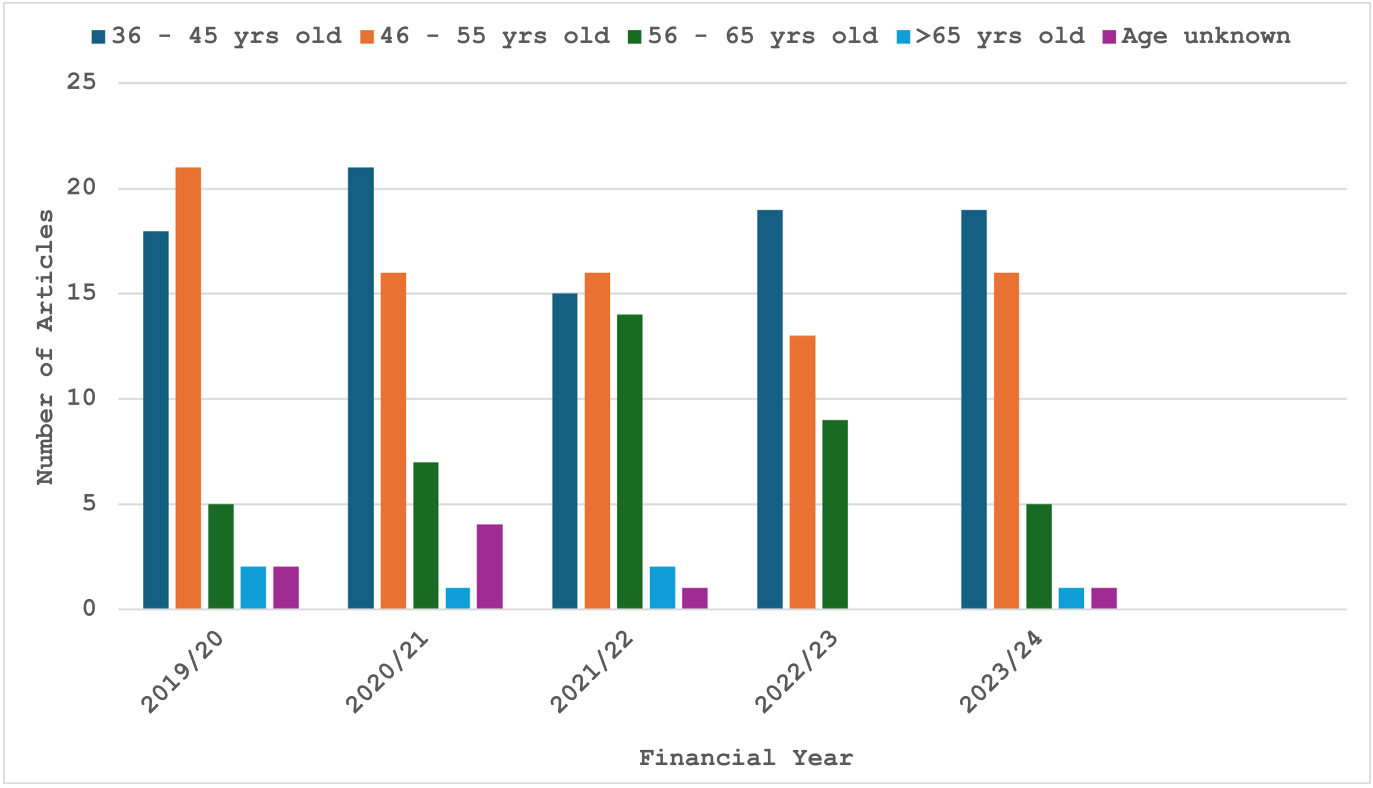

Fig. 5. Age profile of SANBI authors in ISI journals.

African) patterns, with authors of European descent leading at an average of 2.2 publications per author, followed by Indigenous Africans, Indians/Asians, and authors of mixed ethnicity at an average of 1.7 publications per author. The collaborative efforts and partnerships with regional and international partners yielded a sizeable number of publications (captured here as non-South African Authors) with an average rate of 2.7 publications per author. SANBI's research and knowledge outputs have leveraged data and information gleaned from biodiversity collections (i.e. both living and dried herbarium specimens) to elucidate the taxonomy and systematics of various taxa (based on phenetics, numerical taxonomy, alpha taxonomy and providing new and/or updated species descriptions), assessment of threatened and endangered species, and detection of alien and invasive species, ecosystems mapping, restoration biology, global and environmental change and eco-physiological responses; and more recently outputs have covered topics on marine biology, elucidating species distributions in relation to geographical and environmental patterns, pathogens, vector-borne diseases on wildlife.

The external review of SANBI's Biodiversity Science and Policy Advice work (SANBI, 2018) alluded to several challenges facing the Institute, and critical amongst these was the notable erosion/loss of capacity in several mandate areas such as taxonomy, horticulture and climate change due to retirement and/or resignations without effort for their replacements. The review also noted that, despite the existence of a strategy for plant taxonomic research in South Africa 2015–2020 (Victor et al., 2015) and the strategy for zoological taxonomy (Hamer, 2013), the research at SANBI was pursued largely without a formal overarching strategic framework with clear priorities in the medium to long term, and as such recommended the development of a comprehensive SANBI wide Research Strategy to prioritize research efforts across the various programs in SANBI. Informed by gaps in plant taxonomic knowledge, research efforts in SANBI have for the past decade focused on three progammes, notably the e-flora programme intended to produce an open access online flora for South Africa, taxonomic revisionary work on priority plant genera (based on the date of last revision for the genera, proportion of identified specimens in SANBI herbaria, proportion of taxa classified as data deficient, economic importance, and proportion of infra-generic taxa in South Africa), and plant collecting programme, mainly to biodiversity hotspots to improve coverage and representation of south Africa's flora in SANBI herbaria. The development of a SANBI wide research strategy was influenced and informed by other national policies, notably the Department of Science and Technology (2019) emphasizing the need to build on South Africa's success in growing a strong science system with a threefold increase in publications, significant growth in the participation of black people and women in the R&D workforce, and a rise in doctoral graduation rates.

SANBI's Research Strategy (SANBI, 2020) aims to 'build networks of excellence and impact where a combination of research modalities (undertaking, coordinating, convening, catalyzing, synthesizing) provides integrated national-scale knowledge and evidence to guide policy and decision making; and to provide knowledge to improve the quality of SANBI's products and services and increase the impact of the National Botanical and Zoological Gardens'. These aims are pursued through four strategic objectives, namely (a) a platform of foundational biodiversity knowledge and information is available to inform priority applied and strategic projects; (b) the state of biodiversity, including pressures and responses, is assessed and findings are used to inform policies and decision making; (c) integrated knowledge and evidence on priority issues is provided to inform policy, decision making and actions; and (d) the value and impact of national gardens collections are enhanced through the strategic application of research projects and maintaining research infrastructure. Under these strategic objectives several research initiatives have been developed, focusing on improving and updating species taxonomy and classification, species abundance, diversity and distribution mapping; foundational genetic research to support biodiversity and regulation; support for One Health - modelling of pathogens, vectors and host diversity interactions in a changing world; and research to improve ecosystem mapping and classification across all

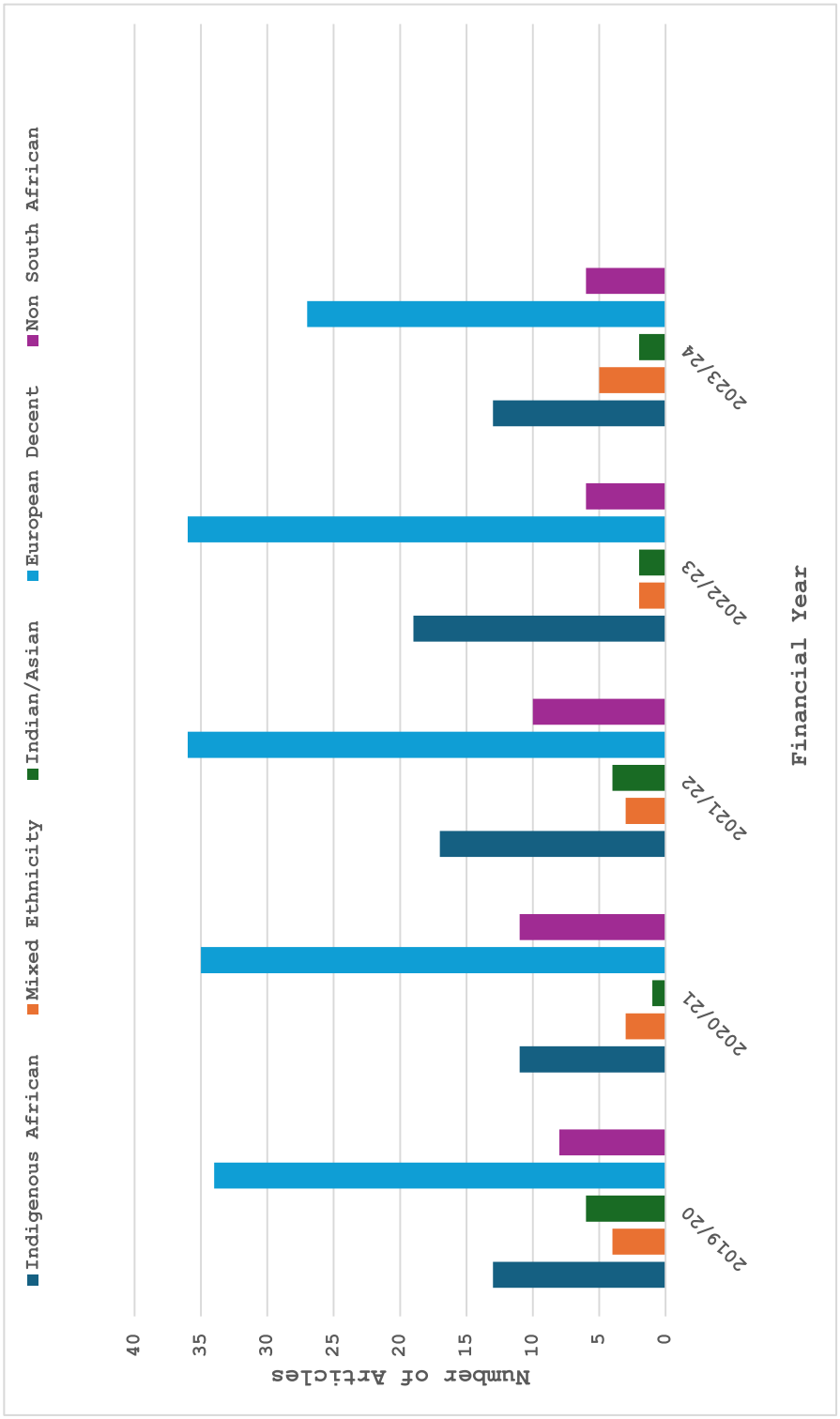

Fig. 6. Population group profile of SANBI Authors in ISI journals.

realms (terrestrial, freshwater, marine, and estuarine), as well as the mapping of ecological infrastructure. The research outputs and knowledge products (mainly peer reviewed publications, books and book chapters) of SANBI have been aligned to these objectives since 2021.

Through collaborative effort with several partner institutions and organizations nationally and internationally, SANBI is able to produce and make available major products as per the mandate on a regular basis, such as the Plant Red Data List and assessments of threatened species, the National Checklists (for Animals and Plants), the National Biodiversity Assessment, the status reports on Biological Invasions, and GMOs released into the environment. These products have become important resources and benchmark references to inform policy decision-making and planning on the protection of critical biodiversity areas, and they enable SANBI to "report on the status of the Republic's biodiversity" in terms of the NEMBA (Act 10 of 2004) S11 (1)(a)(i).

3.3.3. Investments in research infrastructure

In line with its mandated function to '*establish facilities for horticulture display, environmental education, visitor amenities and research*' SANBI has prioritized the establishment, maintenance, protection, and preservation of collections both living (in national botanical gardens) and dried plant specimens (herbaria) with an annual budget allocation from infrastructure budget, and a strategy and programme forecast up to 2029/30 (SANBI Infrastructure Master Plan, 2023). Through the Infrastructure programme, SANBI has managed to procure and maintain specialized research equipment, with supplementary funds from research grants from government departments (e.g. DSTI) and research organizations (such as the NRF) thus enabling SANBI to participate in cutting edge research with partner organizations nationally and/or internationally. SANBI has invested in the acquisition of New Generation Sequencing equipment as well as revamping laboratories generating genetic level evidence for species identifications and assessing phylogenetic relationships, a service that is increasingly relied upon in forensic investigation of cases involving livestock and wildlife (cycads and succulent plants) poaching. Important research infrastructure and equipment include dedicated laboratories for DNA extraction, PCR, sequencing and a DNA-free lab that ensures the integrity of the processes through a one-way flow under scientifically accepted protocols and guidelines. These laboratories host a variety of maintained and calibrated state-of-the-art equipment for automated DNA and RNA extraction, laminar flow hoods, gel documentation images, thermal cyclers and real-time PCR used for SNP-chip analysis, next- generation sequencing, as well as two genetic analysers used for sequencing and microsatellite analyses. These facilities, in addition to bioinformatics, conservation genetics and molecular disease epidemiology research and wildlife forensics and conservation genetics services, allow SANBI to facilitate and promote all scientific research in molecular systematics, ecology and conservation biology with DNA-level research orientated services in line with its mandate on taxonomy.

In addition to maintenance of strategic biodiversity collections' related infrastructure such as storage facilities, equipment for handling collections, and ambient environmental conditions (Natural Science Collections Facility, 2021) at the three herbaria (NBG, NH, and PRE), SANBI was entrusted by the biodiversity biobank community in South Africa to house the Automated Robotics Freezer for storage of plant DNA materials and to allow free and open access by the research community and share information. A Biodiversity Science Collections Hub is in the planning stage to be erected at the Pretoria National Botanical Gardens. This is SANBI's contribution and support to the Department of Science Technology and Innovation's vision under the South African Research Infrastructure Roadmap (SARIR) programme to consolidate and allow for enhanced access, through electronic streaming of digital images of natural history collections housed across institutions in South Africa. Both the Wild Plant Seed Bank and the Wildlife Biobank participate in a national platform, the Biodiversity Biobanks of South Africa (BBSA) that is funded by the DSTI to provide a coordinating and supporting mechanism across existing biodiversity biobanks nationally, with the main aim of increasing the range and quality of samples stored and distributed and increasing and improving access for research and development.

3.4. Role in human capital development

3.4.1. Strategic leadership

SANBI's commitment to development of human capital and transformation is informed by its mandate "to address historical imbalances, enable and facilitate transformation and to achieve equity within all branches of the biodiversity sector". The National Biodiversity Framework 2007, amongst others, called for a national strategy to address transformation and development of scarce skills as priority in the South Africa's *Second National Biodiversity Strategy and Action Plan 2015–2025* (Department of Environmental Affairs (DEA), 2015). SANBI, being one of the institutions in South Africa with the highest (ca. 200) concentration of biodiversity scientists and practitioners (taxonomists, ecologists, horticulturalists), has taken the responsibility for leadership in the broadly defined biodiversity and conservation sector to build the talent pipeline. Strategic partnerships are pursued in the sector to build a sustained pipeline of technical skills and competencies required to undertake biodiversity work. In response to the National Biodiversity Framework (2007), SANBI forged a partnership with GreenMatter through a memorandum of understanding and received a catalytic base funding from the Lewis Foundation (www.thelewisfoundation.co.za) to coordinate the development of a sector wide strategy, the Biodiversity Human Capital Development Strategy (BHCDS) (2010–2030) and related programmes to drive a systemic approach for developing skills in biodiversity and transformation in pursuit of *'a socially equitable and suitably skilled workforce of biodiversity leaders, professionals and technicians to optimally implement the sector's expanding and increasingly complex mandate'*. The goals of BHCDS (SANBI and Lewis Foundation, 2010) are to increase the number of talented black South Africans *attracted* to working in the sector; improve the *quality, levels and relevance of skills* for the sector; improve the *retention and effective deployment* of suitable individuals in the sector, and to create *enabling macro-conditions* for skills planning, development and evaluation. SANBI has been committed to offer equal opportunities to all its employees within the framework of lifelong learning, improve the advancement of previously disadvantaged employees, increase the levels of investment in education and training, and meet the objectives determined by career paths and to support succession planning within the Institution. Staff at SANBI (full time and term contracts) have benefited from a further studies programme, that for the past decade supported full-time studies towards higher degrees (i.e. Honors, Masters, and Doctorates) through a variety of sources such as the Joan Wrench Kirstenbosch Scholarship Fund, Biosecurity/Biological Invasions, and the NRF (Table 4).

3.4.2. Internships

SANBI has over the years implemented internship programmes with the aim of exposing graduates to career possibilities in biodiversity research/science, and to provide hands-on training in the specific skills areas required to achieve SANBI's research and science mandate. A flagship internship programme for SANBI called Groen Sebenza, which literally translates to 'green jobs', was first implemented in May 2013 for a period of two years as part of the Government's Jobs Fund Pilot Project aimed at developing priority skills in the biodiversity sector to create sustainable job opportunities. Over the two-year period, this programe under the leadership of SANBI recruited over 800 unemployed graduates in the biodiversity sector,

Table 4
Number of Scholarship and Fellowship Beneficiaries funded by SANBI for the period 2011 - 2024. * Status as of 31 December 2024.

Studies supported	Complete	Incomplete* /Ongoing
Honors	**22**	**0**
MSc	**28**	**7**
PhD	**7**	**3**
Post-Doctoral Fellowships	**24**	**3**

involving 43 partners as host institutions from all tiers of government, non-governmental organizations and private companies in the biodiversity sector (SANBI, Annual Report 2013/14). Participants in the internship programme, who were referred to as Groen Sebenza pioneers, received occupation specific skills development and training as well as workplace experience at the host institutions to maximize the pioneers' opportunities for success in obtaining sustainable jobs in the sector. A second phase of the programme, Groen Sebenza II Internship, also coordinated and led by SANBI with funding from the DFFE enrolled over 1 050 graduates through 79 participating host institutions ranging from government, non-governmental organizations, to the private sector for a two-year period starting 2023. This is one of the major skills development and job creation programme aimed at developing priority skills in the biodiversity sector, equip graduates with various life and generic skills training to create sustainable job opportunities. As the project ended in December 2024, at least 340 of those who were on the programme had found employment in the biodiversity and conservation sector.

SANBI runs a Fellows programme through which retired senior scientists and professionals are retained to continue contributing to the ongoing work of SANBI, and importantly to mentor young scientists while benefiting from access to SANBI facilities and retention and use of SANBI email address. Over the years this programme has retained more than ten retirees who are experts in their fields and SANBI continues to benefit from their vast knowledge and expertise. In addition to mentoring, most of the fellows participate in co-supervision of staff, students, collaborate on strategic projects and contribute to SANBI publications.

3.5. Strategic partnerships and resources mobilization

SANBI has endorsed an approach and practice of working with, and through partnerships as prescribed by its policy on Network of Partners to leverage external resources to achieve the biodiversity mandate. Through this approach, SANBI is able to deliver on key outputs in a relatively short space of time by coordinating and facilitating contributions from a large pool of experts to leverage and utilize data and staff time from any institution. Important SANBI mandate deliverables such as the National Biodiversity Assessment (NBA), the status reports on Invasive and Alien Species, and Genetically Modified Organisms (GMOs) as well as the National Species Checklists are all made possible through collaboration and partnerships that SANBI has established with several individuals and organizations nationally, regionally, and internationally. For example, through the development of the national biodiversity assessment (NBA) SANBI has, and continues to work collaboratively with over 470 individuals from 90 institutions with relevant research interests and expertise aligned to the scope of work, the vast majority on a volunteer basis without any financial compensation (SANBI, 2019; 2024) except for acknowledgement and recognition as contributors. The convening and coordination role of SANBI in the biodiversity and conservation sector has been recognized within the national system of innovation. This role led SANBI to be the preferred institution under the SARIR program of the DSTI to lead the development, coordination and implementation of three national projects, namely the Natural Science and collections Facility (NSCF), Biodiversity Biobanks research facility, and the Living Collections cluster project. Through these mega projects, SANBI is able to partner with museums (national and provincial), Science Councils, Research Facilities of the NRF and Universities to mobilize biodiversity data and leverage a range of expertise nationally to document South Africa's biodiversity at a faster rate. A recent (January 2025) register of SANBI memorandum of understanding lists no less than fifty-five partner organizations, spanning from research institutes/councils to museums, universities, government departments and municipalities, and non-profit organizations, representing a wide pool of expertise from which SANBI draws relevant inputs and contributions to a variety of knowledge products and services.

The National Revenue supports the biodiversity and conservation mandate at three spheres of government (national, provincial and local) and there are disjointed efforts amongst these leading to duplication of efforts and suboptimal use of resources. Reliance on the National Revenue to fund the operations of most state entities has become unreliable lately, and as such entities are forced to increasingly find alternative sources of revenue generation to augment their government grants. SANBI is no exception, and in the current uncertainty and unpredictable economic outlook it is important for SANBI to diversify income sources to be resilient and sustainable. Although there has been a substantial investment (ca. R830 million) by government towards infrastructure maintenance and improvement at SANBI since 2013/14 (Table 5), however, close to a quarter of this amount was lost through budget cuts and repurposing during the COVID-19 pandemic – a period when SANBI gardens were closed to the public and could not generate income via entrance fees. With its broad mandate, SANBI is well placed to play an integrative role and as a nerve centre in the provision of scientific services required to support biodiversity management and conservation across the three spheres of government. The eleven national gardens together generate over R150 million income annually through a variety of garden-based activities, plant sales, rentals and admission fees. This income assists in partially offsetting staff salaries and operational costs in the various national botanical gardens. For the past decade SANBI's income reflected an average of 82:18 ratio (Table 5), which is a split between a parliamentary grant and own externally generated revenue through a variety of sources such as entrance fees to SANBI gardens, specialized DNA-based diagnostic and species identification services, research grants to individual researchers (mainly the National Research Foundation, and other national and international sources), large project funding (notably from the Department of Science Technology and Innovation, the Global Environmental Facility, the Kunming Biodiversity Fund, International Climate Initiative, and the Green Climate Fund for ecosystems disaster risk reduction). These are some of the efforts intended to secure additional external revenue and diversify sources of external revenue for SANBI.

The scope for generating, managing and exploiting intellectual properties (IP), including indigenous knowledge (IK) abounds in SANBI as biodiversity conservation and sustainable use is intricately linked to indigenous knowledge (Department of Forestry, Fisheries and Environment (DFFE), 2023a; 2023b). Focus areas of the SANBI mandate offer opportunities for exploring intellectual property (IP) rights, for example in the area of biodiversity data, information and knowledge products and services, horticulture, bioprospecting, and all these hold great potential as future income streams. In the past five years, SANBI has built internal competencies on wildlife DNA diagnostic services to industry, focusing on cycads (*Encephalartos*) and succulent plants (mainly the family Aizoaceae). The incorporation of the NZG into SANBI has brought in DNA-forensic services capabilities focusing on animal species, both livestock and wildlife, except for the Rhinoceros cases that are handled and serviced by the University of Pretoria's Veterinary Genetics Laboratory using a national database, RhoDIS for all rhinos and horns in line with government legislation.

Table 5
SANBI's historical revenue and income patterns. (Source: SANBI Annual Reports, https://www.sanbi.org/about/annual-reports/sanbi-annual-reports-overview).

Revenue		2013/14 (Rand)	2014/15 (Rand)	2015/16 (Rand)	2016/17 (Rand)	2017/18 (Rand)	2018/19* (Rand)	2019/20 (Rand)	2020/21 (Rand)	2021/22 (Rand)	2022/23 (Rand)	2023/24 (Rand)
Government (MTEF) grant	(A+B)	264 254 000	289 951 000	304 412 000	319 331 000	369 228 000	464 651 000	509 907 026	468 584 833**	581 359 000	541 414 000	593 690 945
	A-Operational	*208 684 000*	*223 447 000*	*227 149 000*	*237 973 000*	*299 228 000*	*393 903 000*	*442 376 026*	*468 584 833***	*500 823 000*	*458 112 000*	*416 716 945*
	B-Infrastructure after budget cuts	55 570 000	66 504 000	77 263 000	81 358 000	70 000 000	70 748 000	67 531 000	0**	80 536 000	83 302 000	176 974 000
Other grants, bequests, sponsorships and donations		251 987 829	305 066 072	77 342 514	142 017 865	104 656 891	65 792 207	68 797 224	76 710 283	101 003 078	181 248 370	235 090 920
Sub Total (MTEF A+B & Other grants)		*516 241 829*	*595 017 072*	*381 754 514*	*461 348 865*	*473 884 891*	*530 443 207*	*578 704 250*	*545 295 116*	*682 362 078*	*722 662 370*	*828 781 865*
Own Income (entrance fees, projects, commercial and others)		59 032 419	81 165 397	87 328 930	100 117 458	114 670 118	174 190 184	151 617 958	65 957 375	104 566 367	219 863 582	195 412 664
Services in kind		00	00	00	00	00	13 607 137	13 074 939	20 852 447	17 466 272	718 548	963 717
Fines, Penalties and Forfeits		00	00	00	00	00	00	00	00	00	00	3 007 632
Sub Total (Own Income)		*59 032 419*	*81 165 397*	*87 328 930*	*100 117 458*	*114 670 118*	*187 797 321*	*164 692 897*	*86 809 822*	*122 032 639*	*220 582 130*	*199 384 013*
Grand Total revenue		**575 274 248**	**676 182 469**	**469 083 444**	**561 466 323**	**588 555 009**	**718 240 528**	**743 397 147**	**632 104 938**	**804 394 717**	**943 244 500**	**1 028 165 878**
Ratio of MTEF/Grants: Own Income		**89.7: 10.3**	**87.9: 12.0**	**81.4:18.6**	**82.2: 17.8**	**80.5: 19.5**	**73.85: 26.2**	**77.8: 22.2**	**86.3: 13.7**	**84.8: 15.2**	**76.6: 23.4**	**60.6: 19.4**

* Accounting for the National Zoological Garden that was transferred to SANBI from 1 April 2018.
** Allocation of R77 838 000 transferred to cover SANBI's operational costs during COVID-19; NBGs closed to the public for four months in 2020/21, NZG closed for five months in the same period.

4. Conclusions

In summary and conclusion, SANBI's gardens are never static; they are dynamic spaces that have been transformed over the years and must continue to adapt to change and address societal challenges. They will also need to consider potential uses and adoption of new technologies, such as artificial intelligence in the gardens' operations to enhance visitor experience. Long term monitoring, innovation and research as well as regular maintenance, upkeep, modernization and alignment with government priorities such as the KISS – Kruger, Kirstenbosch, iSimangaliso Icon Status Strategy of the Minister of Forestry, Fisheries and the Environment, are critical aspects if the gardens are to continue to play a meaningful role in modern society. Consolidation of SANBI's efforts towards a concept of 'Gardens of the Future' augers well to reposition this institution to play a pivotal role in botanical research, conservation, tourism/display/visitor services and education. The key legislated mandate deliverables such as the NBA, Status Reports on Alien and Invasive Species, GMOs, all require unique expertise and specialists for which SANBI should prioritize in its recruitment drive as well as its efforts in skills and human capital development in partnership with institutions of higher learning.

Finaly, in order to ensure long-term sustainability, relevance to tackling societal challenges, become a go-to biodiversity knowledge hub, particularly on South African flora, for science-based solutions in biodiversity planning, management, monitoring and sustainable use, it is important that SANBI continue to invest in modern research infrastructure, development and attraction of competencies and skills to pursue cutting edge research in botanical sciences. The number of peer-reviewed publications in ISI journals, diversity of authorship, impacts and relevance to societal problems are all encouraging signs of SANBI as an institution that has evolved over the years from a narrowly focused to a modern, diverse, relevant, dynamic, and fully functional organization in the national (South Africa) system of science and innovation. The provisions of the National Biodiversity Economy Strategy (Department of Forestry, Fisheries and Environment (DFFE), 2016) and the Bio-Economy Strategy (Department of Science and Technology (DST), 2013) create opportunities for SANBI to participate in, and benefit from a range of programmes under these national strategies with scope directly linked to the mandate of SANBI. These national strategies call for partnership and collaboration with key institutions such as the Agricultural Research Council (ARC) for crop wild relatives, and the Council for Scientific Research and Industrial Research (CSIR) for plant-based natural products in pharmaceuticals, and other industrial applications.

Declaration of competing interest

The authors declare no conflict of interest.

CRediT authorship contribution statement

Ramagwai Joseph Sebola: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Christopher K. Willis:** Writing – review & editing.

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