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Review of policies for biodiversity informatics in Southern Africa: Case studies of Botswana and South Africa

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Acknowledgments

Abstract

Conservation and management of biodiversity data is crucial for Sub-Saharan Africa countries. As signatories to the Convention on Biological Diversity (CBD), Botswana and South Africa have undertaken to abide by what has been stipulated by the CBD and to endeavour to provide legislative, administrative and policy measures towards achieving biodiversity data management. This article reviews policy and legislation instruments in order to identify their weaknesses and strengths and come up with recommendations for effective biodiversity data management. The methodology employed was a qualitative content analysis of relevant legislations in Botswana and South Africa. Results reveal two contrasting situations. South Africa has made significant progress in developing policies, enacting biodiversity-related legislation that emphasizes their commitment towards the collection and use of biological diversity data for the sustainable progress of the country. However, these pieces of legislation need to review and consolidate the laws relating to biodiversity informatics and to develop a biodiversity policy together with an implementation plan. These are important to inform the overall national development agenda. In Botswana, the issues are more related to absence of legislations addressing biodiversity data management. Biodiversity informatics is not mentioned in any policy or legal document. There is therefore a need to revisit the policy and legislative instruments because there have been huge changes in the technologies for remote and field biodiversity data collection, data storage, big data analysis, data visualization, informatics infrastructure development, capacity building, outreach and open access initiatives.

Keywords: biodiversity; Botswana; informatics; institutions; policy; South Africa.

1. Introduction

Many regions and countries in Sub-Saharan Africa are endowed with rich biodiversity that contributes through provisioning, regulating, cultural and supporting ecosystem services to many constituents of human wellbeing, including security, basic material for a good life, health, good social relations, and freedom of choice as well as action [1]. The Southern African region has a rich natural heritage of global significance to the world's climate and biological diversity – or 'biodiversity'. South Africa ranks as the third most biologically-diverse country in the world. Botswana has Africa's largest elephant population.

However, Botswana and South Africa, like other biodiverse regions of the world, are experiencing rapid and extensive rates of biodiversity loss, primarily as a consequence of development-related habitat conversion [2, 3]. However, a better understanding of the reasons for the loss in biodiversity has led to intensified efforts to conserve it. Biodiversity conservation has emerged within the past two decades as one of the most important global challenges confronting national planners, world bodies, professionals and academics.

At a recent regional consultation dialogue, African countries' governments reported their failure to achieve the 2010 Aichi biodiversity targets, citing the challenges of insufficient integration and prioritization of biodiversity into broader sector of the economy. Concerns were also raised by governments about the failure of the scientific community to articulate biodiversity issues effectively to policymakers in ways that make biodiversity a priority in national development agenda. Following the disappointment of missing the 2010 biodiversity targets, governments launched an ambitious and elaborate Strategic Plan for Biodiversity 2011-

2020, which targets the sustainability of resilient ecosystems and provision of essential services by halting biodiversity loss by 2020 [4]. It has become urgent for policymakers to define appropriate policies that would slow and end the rapid rate of biodiversity loss. A major barrier to achieving the 2010 Aichi biodiversity targets was the poor integration of biodiversity information into decisions in different sectors of the economy other than in nature protection and conservation.

The availability of and access to high-quality information on biodiversity is essential for making effective biodiversity policies. On the other hand, the existence and implementation of policies is critical to the generation of high-quality data and information on biodiversity in Sub-Saharan Africa and assuring access to it. This has led to the emergence of a new discipline, '*Biodiversity Informatics*'. Biodiversity informatics plays a central enabling role in addressing sustainability and conservation issues. The review of the global progress made in the field of biodiversity informatics can be grouped in four categories, (i) mobilizing biodiversity data, (ii) standards, protocols, and tools, (iii) informatics infrastructure building initiatives, and (iv) capacity building, outreach, and open access initiatives. Biodiversity informatics encourages the development of new tools, services and standards for data management and access, modeling, data integration and conservation.

Earlier studies have shown that the availability of information is unevenly distributed across the globe [5], highlighting in particular the extent to which biodiversity information in Sub-Saharan Africa countries is limited, non-existent or scattered in varied formats in national laboratories, museums and survey and project reports [6-8]. The wealth of a country has also been shown to be positively associated with data availability [9, 10]. It is suggested that other problems of low-income countries include lack of adequate infrastructure, insufficient expertise, the inaccessibility of research sites due to political upheaval, and difficulties in getting data published or made public [6]. This situation hinders the exchange of information on biodiversity in Sub-Saharan Africa and the creation of a coherent database.

A number of initiatives have been undertaken in different parts of the world to mobilize biodiversity data [11], but these have often focused on high-income countries and relatively little is known about biodiversity in low-income countries. Furthermore, several initiatives are engaged in the development of (1) standards and protocols, (2) collection management tools, (3) geo-referencing and mapping tools, (4) data-cleaning tools, (5) modeling tools and (6) web services and computational frameworks, but these standards, laws and policies are non-existent in low-income countries and those that exist present some gaps in terms of biodiversity data management.

Although many studies have been conducted on strategies that can manage biodiversity data, we know relatively little about the challenges and efforts of countries outside the west to manage it through policy and legislative instruments. It is against this background that this paper seeks to review the existing policy and practice of biodiversity informatics in Botswana and South Africa in order to identify weaknesses and strengths and come up with recommendations for effective biodiversity data management. Following this introduction, the next section elaborates on the methods and data used. The subsequent two sections report on and discuss the results. The final section draws conclusions and provides policy recommendations.

2. Methods and Data

2.1. Study areas

This study, conducted as part of a broader project aiming to review policies that promote biodiversity informatics in Sub-Saharan Africa, focuses on the Southern Africa region and the countries purposively selected are Botswana and South Africa. Both countries are located in the Southern region and are members of Southern African Development Community (SADC)[1]. Both countries are unique in terms of biodiversity richness.
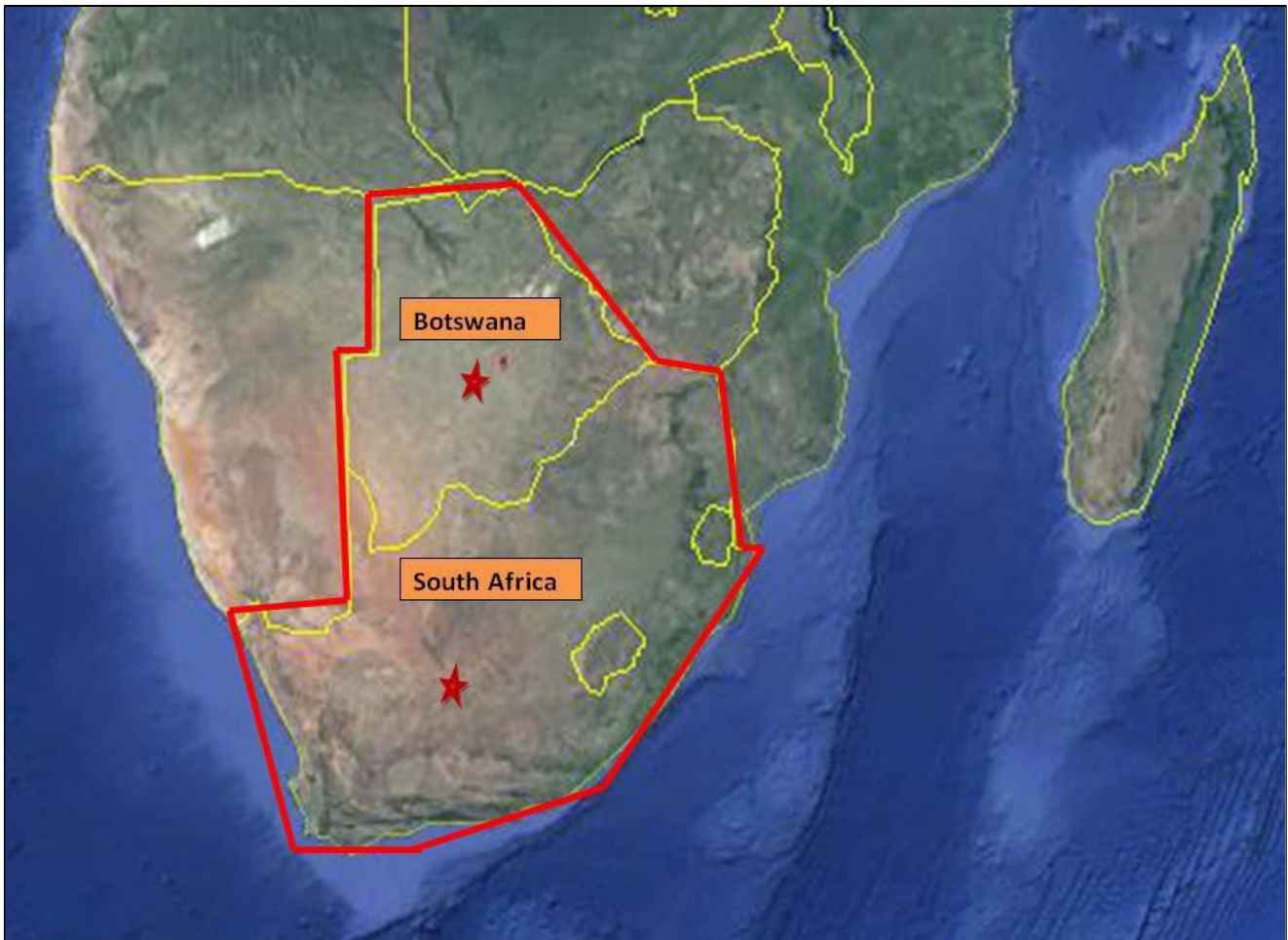
Figure 1: Location of study countries

Based on the internationally agreed criteria established by Birdlife International for key sites for conservation of birds, 12 sites have been identified as Important Bird Areas (IBAs) in Botswana. South Africa is considered as one of the most biologically diverse countries in the world due to its species diversity and endemism as well as its diversity of ecosystems [12]. It is home to over 95,000 known species, contributing a significant proportion to world plant species (6%), reptile species (5%), bird species (8%) and mammal species (6%), with more species regularly discovered and described [13]. South Africa occupies only 2% of the world's surface

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[1] SADC was established under Article 2 of the SADC Treaty which was signed on 17 August 1992 in Windhoek, Namibia. The objectives of SADC are contained in Article 5 of the SADC treaty.

area but is home to nearly 10% of the world's species of plants and 7% of the world's reptiles, birds and mammals [14].

The Worldwide Governance Indicators clearly show that both countries score better than the majority of African countries in terms of control of corruption and governments' effectiveness, with Botswana having a higher score for control of corruption and South Africa scoring slight higher on government effectiveness [15-17]. Botswana's political environment is among the most stable in Africa and has been supportive of prudent macroeconomic and poverty reduction policies [18]. The political framework is based on a parliamentary representative democratic republic, with Botswana's President being head of both state and government. A multiparty constitutional democracy prevails, where each of the elections since independence in 1966 has been freely and fairly contested and held on schedule. The Botswana Democratic Party (BDP) is the dominant party and has consistently been re-elected as the governing political party since independence. This political stability has implications for policy making and effective regulatory frameworks, especially those related to biodiversity. Both countries have stable governments with relatively low corruption and both have adequate economic resources to implement a policy. **Table 1** presents a summary of their key characteristics.

Table 1: Key socio-economic characteristics of case study countries

Countries	Botswana	South Africa
Governance system	Presidential system of Government	Presidential system of Government
Area	566,730 km²	1,219,090km²
Total population	2.02 million (2014)	54 million (2014)
Density	3.9 inhabitants/ km² (2014)	44.5 inhabitants/ km² (2014)
Forest cover	108, 400 km²	92,410 km²
GDP (current US$)	$15.81 billion (2014)	$350 billion (2014)
Government effectiveness[2]	64.90 (2014)	65.38(2014)
Control of corruption[3]	75.96 (2014)	54.33 (2014)

2.2. Data collection

This study is a qualitative one carried out via content analysis of data collected from secondary sources and from policies as well as the numerous legislative instruments that relate to the conservation and management of biodiversity. In this regard, the websites of the following key institutions in both countries have been extensively searched in Botswana and South Africa:

- Ministry of Environment, Wildlife and Tourism (MEWT);

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[2] (Percentile rank ranging from 0 (lowest) to 100 (highest))
[3] Percentile rank ranging from 0 (lowest) to 100 (highest))

- Ministry of Minerals, Energy and Water Resources (MMEWR), which coordinates development and operational activities in the energy, water and minerals sector;
- Botswana Tourism Board (BTB);
- Department of Wildlife and National Parks (DWNP);
- Department of Environmental Affairs (DEA);
- Department of Animal Production (DAP);
- Department of Forest Resources and Rangelands (DFRR) in Botswana;
- ; Ministry of Environmental Affairs;
- Ministry of Agriculture, Forestry and Fisheries;
- Department of Environmental Affairs (DEA);
- Department of Water Affairs (DWA);
- Department of Agriculture, Forestry and Fisheries (DAFF);
- South African National Biodiversity Institute, South African National Parks (SAN Parks);
- Department of Science and Technology (DST);
- South African Environmental Observation Network (SAEON) in South Africa.

Policies and laws were obtained from the websites of the above institutions.

As far as far as peer-reviewed papers are concerned, we developed a comprehensive search strategy. First we identified articles using paired keyword search terms: "*biodiversity data management*", "*biodiversity conservation in Botswana*", "*biodiversity conservation in South Africa*", "*effectiveness of policies in Botswana and South Africa*", "*implementation of policies in Botswana and South Africa*", available in the Web of Knowledge database. Initially, with no restriction on date of article publication, the web search resulted in 808 journal articles containing a combination of at least two of the keywords. All titles of the identified articles were critically examined and 65 were considered as likely to have relevant information for review. Full texts of the 65 selected peer-reviewed articles were retrieved and information extracted for review.

All available legislation and policies which govern or have an effect on biodiversity informatics were reviewed in order to ascertain whether any conflicts existed. It is important to note that the legislations and policies to be analyzed deal with biodiversity conservation and management in general and were not drafted specifically to regulate biodiversity data management. For the purposes of this article, only those sections of the legislation and policies pertaining to biodiversity data management are analyzed.

2.3. Analytical framework

For a better understanding of how policies can promote or hinder biodiversity data management we have built an analytical framework relevant to biodiversity informatics for the project [19]. The framework is divided into four elements for analysis: 1) Mobilizing Biodiversity Data; 2) Development of Standards, Protocols, and Tools; 3) Informatics Infrastructure development; 4) Capacity Building, Outreach and Open Access Initiatives. We analyzed the above categories focusing on two key elements - policies and institutional structures - that promote or hinder biodiversity informatics in Botswana and South Africa.

Thematic data analysis, a method for identifying and reporting patterns within the data set, was guided by framework [20], particularly the first four levels. This includes: 1) Familiarization with the data; 2) Identifying a thematic framework (coding to reflect the aims of the study and what is emerging from the data); 3) Indexing and Charting (re-arranging data by index - for example, tabular presentation of themes in columns, cases in rows, summaries in cells); 4) Mapping and Interpretation (revising charts to look for patterns and associations in the data, developing explanations, mapping the range of phenomena).

Content analysis was used as a companion research instrument in multi-method studies employing diverse methods to enhance the validity of results by minimizing biases [21]. Content analysis was also conducted to examine the principles, approaches and implementation measures, and the cooperation mechanisms between policy actors and networks at the departmental and political levels. It was further used to examine legislation and control measures and to identify gaps in legislation regulations and the institutional system needed to support the synergy of the policies. Two broad approaches were suggested for documentary analysis: content analysis and context analysis. While content analysis focuses on the document itself, context analysis views the document as a reflection of the wider contextual environment pertaining to the research area [22]. The two approaches were used in this study, but with more use of content analysis. The effectiveness of policies was analyzed through the analysis of available peer-reviewed articles, policy briefs and working papers which reported on whether policy objectives stated in the policy documents were being achieved.

2.4.   Limitations of the study and mitigation measures

This study used content analysis specifically to seek documentation of policies related to biodiversity information and data. Although we acknowledge the existence of policies such as the general 'open government' policy and policy related to scientific capacity and IT infrastructure, this study presents some limitations. First, due to issues of access and availability, we were not able to cover every policy. Secondly, the scope did not include an assessment of the implementation of current policies and interviews with key stakeholders or comparisons with countries outside Africa. In a bid to overcome the challenge of engaging personally with key stakeholders, relevant published government documents were obtained from various agencies through their websites. Hence, the selected policies and legislations which become the samples of analysis are those instruments which could be obtained online. Furthermore, the scope did not consider international institutions or projects for environmental data collection whose mandates might include Botswana and South Africa.

3. Results

3.1.   Biodiversity data management relevant legislation and policy instruments

We analyzed the policies and relevant documents in each country using our conceptual framework. Both countries have policies in place relevant to biodiversity management. However, while each country has taken its own approach to considering biodiversity (and, rarely, direct consideration of biodiversity informatics) in its policies and relevant documents, the review reveals some drivers, barriers and/or gaps in policy and laws in each

country and also in the institutional arrangements (strengths and weaknesses) in relation to biodiversity informatics. A summary of policy and legal instruments in the case-study countries relevant to the analytical framework is presented below (**Table 2**). Each policy/law was marked with an 'x' under the country to which a comment applies. Where a policy or law does not exist, it was left blank.

Table 2: Policy and regulatory frameworks relevant to biodiversity information in Botswana and South Africa

Category	Policy or regulatory instruments	Botswana	South Africa
Mobilizing Biodiversity Data	Forest policy/program: intention to set up a database on forests management		x
	Wild Life Conservation and/or National Parks Act		x
	Forest Act/law/policy: call for biodiversity data collection for the better regulation and protection of forests	x	x
	Biodiversity policy/law/act/ action plans		x
	Biodiversity Strategy and Action Plan: call for the implementation of biodiversity data management		
	Constitutions	x	
	Environmental policy/act/law		x
Standards, Protocols, and Tools development	Signed and ratified international treaties and conventions are found to be relevant for biodiversity information management	x	x
Informatics Infrastructure development	Existence of or call for a national biodiversity database		x
Capacity Building, Outreach and Open Access Initiatives	Environmental policy/law/act		
	National Environment Action Plan framework: Plan for training and research		
	Biodiversity Strategy and Action Plan	x	x
	Constitution: the right to information (including biodiversity data)		x
	Biodiversity policy/law/act: call for training in biodiversity management		
	Environmental Impact Assessment Act: call for access to information		x
	Wildlife conservation policy/act/law		x

It is clear from **Table 2** that both countries are committed to several international conventions that emphasize the protection and conservation of biodiversity. Both countries have also made much progress in creating an enabling environment for such cross-border collaborations (to various SADC environmental protocols signed, TFCAs developed, OKACOM, etc.). However, it is not clear how actively they pursue the SADC protocols, including the Regional Biodiversity Strategy. The recent Gaborone Declaration may prove to be a critical step in renewing regional-level interactions and commitments and may revitalize cross-border commitments [23]. It is also clear that there are national policy and legislation frameworks related to biodiversity. Details of the policy and legal instruments in the two countries are explored further below.

3.1.1. Botswana

There are some relevant elements of policy and legislation related to biodiversity conservation in Botswana. These include the *Wildlife Conservation Policy*, the *Forest Policy*, the *Agricultural Resources Act*, the *Tourism Policy*, the *Tourism Act*, the *Agriculture Policy*, the *Wildlife Conservation and National Parks Act* and the *Constitution of Botswana* itself, as well as the *National Conservation Strategy* etc. For example, the *Forest Policy* is a framework that provides guidance and facilitation in the management of forests and range resources of the country through conservation, development, and sustainable use [24]. The *Agricultural Resources (Conservation) Act*, 1972/1979 calls for conservation of agricultural resources, which are defined as animals, birds, plants, waters, soils, fish, etc. [25]. The *Forest Act* of 1968 provides for regulation and protection of forests and forest produce. The *Tourism Policy* calls for conservation and management of wildlife and control and management of game parks and game reserves [26]. The *Wildlife Conservation and National Parks Act* (1992) provided for wildlife management and conservation through gazetting of national parks, game reserves and wildlife management areas in which wildlife conservation and use is the primary land use [27].

Although Botswana has developed various laws, strategies and policies which guide biodiversity conservation, it is surprising to note that there is no single policy and body of regulation which provide adequate guidance on biodiversity data management. The Constitution of Botswana does not specifically make any mention about environment and biodiversity [28]. The principal legislation governing wildlife conservation and protected areas is the Wildlife Conservation and National Parks Act of 1992 [27], but there is no specific mention of biodiversity data mobilization, informatics infrastructure development, capacity building, outreach or open access initiatives. The Forest act No. 8 of 2005 calls for forest management but fails to acknowledge the importance of forest related data and their management [29]. Similarly, the Wildlife Conservation Policy in 1986 formalizes the provisions for the establishment and conservation of wildlife [30], but there was no single paragraph focusing on biodiversity data management.

However, despite the gaps in national policy and regulatory frameworks, Botswana has ratified international environmental agreements essential for addressing the problem of biodiversity data management. These include the Convention on Biological Diversity (CBD) in Rio in June 1992, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on Migratory Species (CMS), Ramsar (the Protection of Important Wetlands Convention), the Convention to Combat Desertification or Land Degradation, the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on the

Conservation of Migratory Species of Wild Animals (Bonn Convention - 2000), and the Basel Convention on Hazardous Wastes. Some of these, such as the Basel Convention, have been incorporated into domestic law. As well as treaties that have become part of Botswana by incorporation, other treaties which have not been domesticated are also a source of rights recognized by the courts of Botswana [31].

3.1.2. South Africa

The democratic elections of 1994 served as a catalyst for a series of fundamental changes to South Africa's legislation and the policy and institutional framework for biodiversity conservation [32-35]. In 1995, the South African Government initiated a national consultative process to develop a policy and strategy for biodiversity conservation that would reflect the interests and aspirations of all South Africans [36, 37]. The legal framework that has the direct major bearing for the regulation of biodiversity conservation and management in parks consists of the National Parks Act (No. 57 of 1976), the Environmental Conservation Act (No. 100 of 1982), the National Forest Act (No. 84 of 1998), the Environmental Conservation (ECA) Act (No. 73 of 1989), the World Heritage Convention Act (No. 49 of 1999) and the National Environmental Management Act (No. 57 of 2003) [38-42].

South Africa passed its first dedicated environmental statute, the Environmental Conservation Act (ECA) (No. 100 of 1982), Glazewski (2000) noted that, the ECA did not live up to its stated purpose of coordinating environmental matters within government. The Act also did not include any substantive provisions regarding environmental management. Consequently, the Act was repealed and replaced by the Environmental Conservation Act (No. 73 of 1989). This second Environmental Conservation Act formed the foundation of environmental conservation and management in protected areas. It stated that environmental policy must be applied with a view to the protection of ecological process, natural systems and natural beauty as well as the preservation of biotic diversity in the natural environment and promoting sustainable utilization of species, effective protection and management of cultural resources, and environmental education in order to establish an environmentally literate community with a sustainable way of life [43].

The National Environmental Management Act, NEMA (No.107 of 1998), sets out principles for the effective management of the environment, with which all organs of the state have to comply in their decision-making. The Act also requires national and provincial departments to compile environmental implementation plans. Although NEMA has set a significant platform for biodiversity conservation, details of how to govern national parks were not clearly delineated. To address the gap the government introduced the National Environment Management: Biodiversity Areas Act (NEM: PAA) (No. 57 of 2003) within the framework of the National Environmental Management Act (No.107 of 1998) [44] .

However, the constitution is the highest law in South Africa. Section 24 of the South African Constitution (Act 108 of 1996) notes the human right to have the environment protected in ways that ensure conservation and sustainable use. The Section reads as follows:

'Everyone has the right (a) to an environment that is not harmful to their health or well-being, and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that (i) prevent pollution and ecological degradation; (ii) promote conservation; and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development' [45].

It is important to note that the Constitution takes an anthropocentric approach to environmental protection and the sustainable use of natural resources: "*Every*one (not everything*) has the right…*" This anthropocentricity regarding environmental management is also echoed in Section 2(2) of NEMA, which states that:

'Environmental management must place people and their needs at the forefront of its concern, and serve their physical, psychological, developmental, and cultural and social interests equitably' *[46]*.

In the context of biodiversity conservation, Section 24(b) (iii) finds specific application. It can be argued that the main aim of any conservation initiative is not only the promotion of conservation but also the promotion of biodiversity data management in order to plan, implement and assess that initiative. It may be argued that to give effect to the right contained in section 24(b) (iii), biodiversity data management may be construed as being part of biodiversity conservation.

Other sections of the Constitution call for access to information. For example, section 32 provides for a right of access to information against public and private bodies:

'Everyone has the right of access to any information held by the state, as well as to any information held by another person and that is required for the exercise or protection of any rights'.

Access to biodiversity information improves organizational efficiency and service delivery. Significant progress has been made with providing ease of access to scientific biodiversity information that contributes to policy and decision-making, with much of the information being made available via the internet.

This principle is given effect by the promulgation of the National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004) (NEMBA) and the National Environmental Management: Protected Areas Act, 2003 (Act 57 of 2003) (NEMPAA). Chapter 3 of NEMBA calls for the development of a National Biodiversity Framework. The National Biodiversity Framework (NBF) was published on 3 August 2009 in terms of Section 38 of NEMBA. The purpose of the NBF is to provide a framework to coordinate and align the efforts of the many organizations and individuals involved in conserving and managing South Africa's biodiversity.

The importance of biodiversity conservation is internationally recognized and addressed in international instruments that South Africa has ratified. These include amongst others the United Nations Convention on Biological Diversity, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Convention on the Conservation of Migratory Species of Wild Animals. At an African regional level, the New Partnership for Africa's Development (NEPAD) placed strong emphasis on biodiversity conservation across state borders for uplifting impoverished rural people while improving national economies

through global tourism. At a regional level, the Southern African Development Community (hereafter SADC) has approached the issue of biodiversity conservation in its Protocol on Wildlife Conservation and Law Enforcement (1999), which covers the sustainable use and conservation of wildlife.

3.2. Institutional frameworks related to biodiversity data management

Although Botswana and South Africa have shown a commitment to biodiversity conservation in their laws, regulations and policies, whether they have allocated sufficient organizational, human, and financial resources and created adequate incentives in practice to put the policies and regulations into effect is less clear. To answer this question requires a focus on administrative organization, centrally and sub-nationally, the role of scientific organizations, Botswana and South Africa's linkages to international donor agencies, and the development of non-governmental organizations. The roles and responsibilities of key institutions directly and indirectly involved in biodiversity conservation and protection in Botswana and South Africa are summarized in **Table 3.**

Table 3: Key institutions directly and indirectly involved in biodiversity conservation and protection in Botswana and South Africa

Country	Key institutions	Key responsibilities
Botswana	Ministry of Environment, Wildlife and Tourism (MEWT)	Responsible for environmental management coordination, environmentally related research permits, plant import and export licences, CITES issues (plants), Agricultural Resources Act, forestry policy, forestry inventories, forestry conservation, forest reserves, collection and distribution of tree seeds, seed storage, propagation and conservation inside National Parks and game reserves, CITES faunal species, protection of certain animal species throughout Botswana, Wildlife Research, implementation of the NCS, National Focal Point for the CBD, UNCCD, Ramsar and Stockholm Conventions, Environment Impact Assessment Law, environmental research, environmental education, GEF Focal Point
	Ministry of Agriculture (MOA)	Responsible for National Gene Bank, long-term storage of seed, agricultural research, including germination and propagation, micro-organisms, agricultural herbarium, biosafety framework, wild crop relatives, micro-organisms, indigenous livestock species, control of pathogenic micro-organisms, conserving agricultural natural resources through the promotion and adoption of appropriate technologies and management practices and research. Some of the relevant departments include Department of Animal Production (DAP), Department of Crop Production (DCP) and Department of Agricultural Research, Statistics and Policy Development (DAR)
	Ministry of Minerals, Energy and Water Resources (MMEWR)	Coordinates development and operational activities in the energy, water and minerals sector. It is mainly responsible for aquatic weeds control, aquatic plant herbarium (proposed), and sustainable water abstraction. Department of Water Affairs administers the water law and other related legislations, and liaises with the riparian users of national and international rivers on the saving, conservation and protection of water resources
	Ministry of Finance and Development Planning	Responsible for mobilizing funds, coordinating the National Budgeting and allocating them to sectors, controlling and monitoring of Import and export of genetic resources
	Ministry of Infrastructure, Science and Technology (MIST)	Responsible for research, science research permits. Within this Ministry, there is a Department of Research Science and Technology (DRST) which provides leadership in science and technology in Botswana through the provision of an enabling policy and legislation environment and coordination of science and technology activities in the country
	Botswana Tourism Organization	Responsible for marketing and promoting Botswana tourism industry and wildlife conservation and management
	Botswana Technology Centre	Responsible for aligning research, science and technology products and services, including biodiversity-related technology
	NGOs (KCS, ST, TSF, TL Birdlife Botswana, Conservation International-Botswana, IUCN, etc.) [4]	Responsible for formulation of project concepts, technical assistance on project management, funding or resource mobilization, bird counts, education, advocacy, bird-related research, wildlife conflict, natural resource management, natural resource conservation, agrobiodiversity conservation
	University of Botswana	Responsible for plant research, herbaria, fungi, algae and micro-organisms, rangeland research and wildlife research in certain areas to assess the environment
South Africa	Department of Environmental Affairs (DEA)	Responsible for ensuring the protection of the environment and conservation of natural resources, balanced with sustainable development and the equitable distribution of the benefits derived from natural resources. It fulfills its mandate through formulating, coordinating and monitoring the implementation of national environmental policies, programmes and legislation, and through undertaking appropriate re-

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[4] The list of NGOs involved with natural resource management and biodiversity conservation is not exhaustive, and more NGOs and CBOs involved in environmental conservation can be found in the Directory of Non-Government Organizations and Community Based Organizations.

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	Department of Water Affairs (DWA)	Responsible for managing freshwater ecosystems with DEA, primarily responsible for the formulation and implementation of policy governing the water sector and has overriding responsibility for water services provided by local government
	Department of Agriculture, Forestry and Fisheries (DAFF)	Responsible for Acts related to the agriculture, forestry and fisheries value chains from inputs, production and adding value to retailing
	South African National Biodiversity Institute (SANBI)	Responsible for maintaining the biodiversity advisory data platform and playing a leading role in South Africa's national commitment to biodiversity data management, particularly in relation to the biodiversity research agenda, provision of knowledge and information, policy support and advice, monitoring and reporting on the state of biodiversity and managing botanical gardens. The Institute presently administers eight national botanical gardens, three research centers, several environmental education programs and field research
	The South African National Parks (SANParks)	Responsible for conserving, protecting, controlling and managing a system of national parks and other defined protected areas and their biodiversity
	Provincial Departments of Environmental Affairs and Provincial Conservation Authorities	Ha a mandate to work throughout the province concerned, both inside and outside protected areas, while in other cases they have a mandate to work only within protected areas (including the development and promotion of ecotourism facilities within protected areas)
	Local government (municipalities)	Have jurisdiction over significant natural resources in urban and rural areas
	Non-Governmental Organisation (NGOs)	Play a vital role in the biodiversity sector, including through corporate funding which would not be possible for government to access; NGOs are able to innovate and be flexible, and they often work in partnership with the public sector

In Botswana, there is no government institution with overall responsibility for biodiversity. Several Government ministries and institutions have a stake in biodiversity conservation and sustainable use, and it is not always clear who has the ultimate responsibility for certain activities (**see Table 3**), as areas of responsibilities sometimes overlap [47]. For example, NEWT has brought four departments [1) Department of Environmental Affairs (DEA), 2) Department of Forestry and Range Resources (DFRR), 3) Department of Wildlife and National Parks (DWNP), 4) Department of Tourism (DOT)] involved with the same tasks. While DEA promotes environment based projects for the conservation and protection of environment, DFRR conserves, protects, and manages vegetation resources and DWNP conserves and manages the country's fish and wildlife resources.

Similarly, in South Africa there are several institutions that are mandated with the conservation and management of biodiversity. This includes national departments, public entities, provincial departments and agencies, municipalities and a range of active NGOs [13, 48-50]. Some of the provinces have established statutory Boards which have been given certain nature conservation and/or environmental functions. For example, the Province of KwaZulu-Natal has the KwaZulu-Natal Nature Conservation Board, and the Western Cape Province, the Western Cape Nature Conservation Board [37, 51]. This situation aggravates fragmentation of policy-making on biodiversity conservation management in national parks, although the Presidential Delivery Agreement has catalyzed increased cross-sector collaboration between these various institutions [35].

4. Discussion

4.1. Challenges to effective data management

The challenges discussed include the legal framework; horizontal and vertical administration, and financial and human resources.

4.1.1. The Legal and Institutional Framework

As can be seen in Table 2 in the **Table 2**, Botswana has serious gaps in regard to biodiversity data management. The policy statements are too general and the relationship and inter- dependence of biodiversity data with conservation is lacking [24]. It was unexpected to find that biodiversity informatics is not mentioned in any policy or legal document. Furthermore, as earlier noted, there is no reference to a right to a clean and safe environment in the Constitution of Botswana. The Environmental Law of Botswana does not have provisions for insuring the conservation of environment (biodiversity included) and fails to address the issue of biodiversity data management.

By contrast, South Africa has developed numerous policies and enacted biodiversity-related legislation that emphasizes their commitment towards the collection and sustainable use of biological diversity data for the sustainable progress of the country. These include for National Parks Act (No. 57 of 1976), the Environmental Conservation Act (No. 100 of 1982), the National Forest Act (No. 84 of 1998), the Environmental Conservation

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Act (No. 73 of 1989) (ECA), the World Heritage Convention Act (No. 49 of 1999), the National Environmental Management Act (No. 57 of 2003), the Environmental Protection Act (No. 11/009 of 9 July 2011, etc. However, they tend to function in silos than to target an overall goal of promoting biodiversity management. It would perhaps be useful to synthesize all of the legal texts relating to biodiversity informatics in one document for easy implementation.

4.1.2. Administrative Organization and Enforcement/implementation

Both horizontal and vertical administrative problems adversely affect biodiversity data management. In Botswana, at the central level, protective functions are divided among a large number of agencies, each with different missions. Ministerial levels tend to focus more on policy decisions, and not on undertaking specific activities. Some of the activities identified were reported to be given to departments whose mandate is far removed from biodiversity [52]. Furthermore, the problem of vertical integration is much more intractable, and it parallels the difficulty Botswana has faced in coordinating biodiversity conservation activities [31]. Key implementation activities were very much tied to the district level. An issue arising with implementation is that no clear departmental level responsibility has been given for some of the tasks. This challenge goes beyond the delegation and coordination of tasks [23]; it also includes the collection and sharing of data.

In South Africa, Botha (2004) notes that its fragmented laws impede implementation and are a threat to successful biodiversity conservation. It is vital to ensure integration and synergy among the suites of environmental laws. Achieving this would minimize confusion (for landowners, the public, conservation agencies and the arms of government) and would promote national cohesion in the approach to conserving biodiversity inside and outside state-owned protected areas.

4.1.3. The low data management capacity of available services and the level of biodiversity technology development and use

Sound planning and biodiversity technology development rely on sound data. Unfortunately, in Botswana, knowledge of individual species and ecosystems is limited. The biological sciences are in an early stage of growth in Botswana, and taxonomy is particularly underdeveloped. This adversely affects the development of comprehensive databases on biodiversity. In terms of data accuracy, it is important to note that data in Botswana are not yet systematically collected according to ecoregion boundaries. Instead, they tend to be collected at the administrative district or other levels, which may incorporate portions of more than one ecoregion [23]. Accessibility of biodiversity data and data formats (i.e. because records are not computerized) are a constraint in Botswana, which often leads to duplication of data collecting and at worst not including important biodiversity data in analyses.

4.1.4. Human and financial resources

The human resource issues, especially in Botswana, are typical of developing countries. The three most common obstacles to successful implementation of biodiversity data management appear to be resources,

finance, and capacity –in terms of both available personnel and their skills [23]. The main biodiversity expertise in the country is divided between the University of Botswana (UB), Botswana College of Agriculture (BCA)**,** and Government Departments and institutions involved with environmental and biodiversity issues. While the University of Botswana is fairly strong in the environmental field, there is still a great need to train students specifically in biodiversity conservation and to increase informatics' expertise in the country [47]. This implies that before passing new policies, policy or decision makers should take into consideration the feasibility policies have of being implemented, enforced, and managed successfully.

4.2. Efforts to biodiversity data management

No country has resolved the competitive pressures between economic development and the conservation of endangered/threatened species and ecosystems. This paper has emphasized problems in the policy and practice of biodiversity conservation in Botswana and South Africa, but it would be unbalanced if it did not acknowledge the Botswanan and South African approaches that appear to have advanced conservation goals.

4.2.1. Mobilization of biodiversity data

The central government in South Africa has made some progress in improving the availability of and access to biodiversity data and the promotion of exchange of information. In South Africa, the Biodiversity Advisor web portal draws together many individual biodiversity information websites with clear guidelines on how to use the information for biodiversity planning, research and land-use decision making. The website provides access to more than 14 million biodiversity records, hundreds of GIS maps and many biodiversity plans [35]. SANBI has built a reputation in biodiversity conservation beyond its national boundaries, becoming more of a regional institution spearheading the field of biodiversity informatics in Africa. In partnership with the Global Biodiversity Information Facility (GBIF), SANBI have organized a series of training and capacity-building workshops to mobilize African biodiversity data and strengthen regional collaboration and capacity in biodiversity informatics. South Africa has been receptive to foreign advice and recommendations, as well as to new environmental technology.

5. Conclusion and recommendations for promoting biodiversity informatics

It is certainly very clear from the evidence presented above that in Botswana the issues are more related to absence of legislations addressing biodiversity data management. Biodiversity informatics is not mentioned in any policy or legal document. This might be due to the fact that the policy and legal framework has been in existence for many years does not reflect the current issues related to biodiversity data management. Biodiversity informatics as a scientific discipline is at a relatively early stage of development, and was not considered as a priority in the policy of the Botswanan Government. However, this emerging field is revolutionizing conservation efforts and it is very critical for Botswana and other Sub-Saharan Africa countries to use it to protect their natural resources. This is important because the protection and conservation of biodiversity cannot be done without having good information about where protection should be focused.

By contrast, South Africa possesses significant policy and legal frameworks for promoting the conservation and sustainable use of biodiversity. The Constitution, NEMA, NEMBA and NEMPA, etc. all provide substantive provisions which could be used to facilitate biodiversity data management. Many of the policies and laws do not reveal gaps and/or lack of clarity and specificity with regard to biodiversity informatics per se, but the provisions tend to be scattered through a variety of pieces of legislation, which might hinder their implementation. Such an arrangement is prevalent in most Sub-Sahara countries where there are no stand-alone biodiversity policies and institutions. The use of sectoral policies and different institutions to manage biodiversity partially has set up a complicated web of responsibilities, which are sometimes overlapping, and created institutional conflicts.

Biodiversity-relevant policies hold the prospects of providing the strategies and tools for enhancing institutional and human capacity to generate, synthesize, and interpret biodiversity information for conservation decisions, to facilitate sharing of biodiversity data, and to meet consumer needs. Therefore, in Botswana, many laws and policies need to be redefined and harmonized to target biodiversity priorities in a bid to mainstream biodiversity issues into national and local development planning. This also holds true because there have been huge changes in the technologies for remote and field biodiversity data collection, data storage, big data analysis, data visualization, informatics infrastructure development, capacity building, outreach and open access initiatives. It is important for the government of Botswana to develop stand-alone biodiversity policies that prioritize the capture, processing and interpretation of biodiversity data and information as well as encourage best practices for open access database and data sharing.

However, without human and financial resources these policies would not be implemented. This review reveals that sufficient skills, tools, human and financial resources are important requirements for adequate implementation of biodiversity data management, suggesting capacity building in various components of biodiversity informatics. The Government of Botswana should incentivize investments in technologies and innovations for biodiversity informatics from the private sector and the international community.

In South Africa, instead of promulgating a number of diverse and fragmented policy and legal instruments, the Government should unify legal texts around specific issues related to biodiversity data mobilization, informatics infrastructure development, capacity building, outreach and open access initiatives. An overall document that synthesizes all of the legal texts relating to biodiversity informatics should be established and complemented by a policy document, and by technical guidelines developed for its implementation.

As things stand in both countries, the institutional frameworks related to biodiversity informatics need to be revisited by clearly allocating specific roles to institutions for implementing, executing and monitoring each step of the management process, as well as being reconciled with other laws.

In Botswana, there is an urgent need to address horizontal and vertical administrative problems [1] collaboration among central governments, e.g. Ministry of Environment, Wildlife and Tourism (MEWT), Ministry of Agriculture (MOA), Ministry of Minerals, Energy and Water Resources (MMEWR); 2) collaboration between central governments (above the ministerial level) and districts].The agency given

responsibility for implementing biodiversity must also have a clearly delineated authority and adequate expertise, equipment and funds to carry out enforcement functions . Furthermore, biodiversity informatics needs to be given a higher priority, with greater political will and assistance from international development agencies. More tangible measures include clear communication of legislation requirements, a vigorous, target-oriented definition of policy integration; and the enhancement of human and technological capacity.

Conflict of interest

The authors did not declare any conflict of interest.

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