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Review

Setting the scene for achievable post-2020 convention on biological diversity targets: A review of the impacts of invasive alien species on ecosystem services in Africa

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ABSTRACT

Invasive alien species (IAS) are known to pose a serious threat to biodiversity, and reduce the ability of ecosystems to provide benefits to humans. In recognition of this threat and to address the impacts of IAS, Parties to the Convention on Biological Diversity (CBD) adopted Aichi Biodiversity Target 9, which is dedicated to the control or eradication of priority IAS and the management of their introduction pathways by 2020. The achievement of Target 9 relies strongly on the commitment and ability of Parties to set ambitious national or regional targets and achive them, the availability of information and the requisite expertise on invasion biology. Now that the global community is gearing for the post-2020 Biodiversity Framework, it is time to take stock and identify opportunities to improve the performance of the African region beyond 2020. We approached this task by reviewing information on the impacts of IAS on ecosystem services in Africa, as a large proportion of Africans directly rely on ecosystem services, particularly in rural areas. Furthermore, we assessed the expertise on IAS in Africa. Our data sources were National Reports of African countries to the CBD, as well as peer-reviewed scientific literature. National Reports under the CBD provide information on measures taken to implement the Convention at country level, as well as progress towards the achievement of set targets. We found National Reports for 48 (about 90%) countries of which 73% provided feedback on IAS indicating commitment to fight IAS. However, there were few studies within peer-reviewed scientific literature looking at impacts of IAS on ecosystem services in Africa and almost half of the authors were non-Africans. This alludes to limited scientific expertise to inform and support IAS management on the continent. Both the National Reports and scientific literature showed that provisioning services were the most negatively affected by IAS. Also, more than 100 species were listed as problematic. More efforts and resources are needed to document IAS impacts across different realms (e.g. marine, terrestrial and freshwater) and for sub-regional bodies so that more integrated strategies and approaches can be developed. This information is also needed to support the development and implementation of national legislative and regulatory initiatives, as well as to report on international obligations such as the Aichi Biodiversity Targets.

1. Introduction

It is wellestablished that invasive alien species (IAS) are a global threat to biodiversity and human well-being (Hermoso et al., 2011; Vilà et al., 2011; Schirmel et al., 2016). As defined by the Convention on Biological Diversity (CBD), IAS are species whose introduction and/or spread outside their natural past or present distribution threatens biological diversity (www.cbd.int). Increasingly, more evidence of the impacts of IAS on biodiversity and ecosystem services is emerging across terrestrial, marine and freshwater ecosystems. Some of the negative

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impacts of IAS in these ecosystems include decreases in abundance and diversity of native species, significant changes in community structure, as well as extinction of species (e.g. Gurevitch and Padilla, 2004; Weyl et al., 2010; Maoela et al., 2016; Clusella-Trullas and Garcia, 2017). There are numerous examples of IAS having significant negative impacts on resource availability, altering biogeochemical processes, such as nutrient cycling and sedimentation rates and impacting species across trophic levels (Didham et al., 2005; Molnar et al., 2008). In many cases IAS have been identified as a major cause of the decline and loss of indigenous/native species, with several well-known cases in which invasions are strongly linked to extinctions (Gurevitch and Padilla, 2004). Although these types of impacts have implications for ecosystem services and human well-being, they are not well documented.

Since biodiversity ultimately underpins the provision of ecosystem services (Egoh et al., 2009), it can be reasonably assumed that any impacts on biodiversity, and ecological processes specifically, will impact ecosystem services. However, understanding the impact of IAS on specific ecosystem services is necessary for their regulation and management, both as a CBD requirement and also to guard against losses in human well-being. For instance, Katsanevakis et al. (2014) reported that IAS have negative impacts on at least 80% of marine ecosystem services in Europe, including food provision, ocean nourishment, recreation and tourism. Similarly, in South Africa, IAS negatively affect the highly endemic fynbos ecosystem, impacting pollination services, ecotourism and displacing native fynbos plants that are used as tea and in medicine (Pejchar and Mooney, 2009). These impacts are associated with economic losses in countries where they are found. For example, in South Africa, economic losses associated with IAS are: $14 million per year for recreation and tourism; $1.4 billion in water provision; and about $52 per hectare in pollination services (Pimentel et al., 2005). In the United States alone, there are approximately 50,000 introduced species causing major environmental damage and losses adding up to almost $120 billion per year (Pimentel et al., 2005). Negative effects of IAS on ecosystem services and associated economic losses such as the ones described above have serious implications on a continent like Africa where most of the population is poor and directly dependent on ecosystem services for their livelihood (Shackleton et al., 2019). These negative effects could be compounded by other concerns such as climate change, land degradation and agricultural pollution, which Africa is particularly vulnerable to (see Mainka and Howard, 2010).

Across Africa, approximately 62% of the rural population relies directly on biodiversity and ecosystem services for their livelihoods (IPBES et al., 2018). The negative impacts of IAS on biodiversity and ecosystem services threaten potential income, medicines and overall human well-being for both rural and urban populations. In recognition of this significant threat, all African countries have made one or more commitments to several international environmental agreements and targets related to the management of IAS (such as: Aichi Biodiversity Target 9; Article 8(h) of the CBD; Sustainable Development Goal (SDG) Target 15.8; United Nations Convention to Combat Desertification (UNCCD)'s Land Degradation Neutrality (LDN) program; International Plant Protection Convention; and Ballast Water Management Convention, to name a few). CBD's Aichi Biodiversity Target 9 is aimed at IAS as follows: "*By 2020, IAS and pathways are identified and prioritized, priority species are controlled or eradicated and measures are in place to manage pathways to prevent their introduction and establishment*". All African countries are signatories to CBD and should report on this target. The achievement of Target 9 relies strongly on the commitment of the Parties which is underpinned by availability of invasion information and the requisite expertise on invasion biology. In fact, successful implementation of these policies requires detailed data and information on identifying IAS, understanding their ecology and understanding the negative (or positive) impacts and interventions (e.g. both control and regulatory). However, some reports show that little or no progress has been made to reverse the negative trends of IAS in Africa (UNU-IHDP, 2012; Tittensor et al., 2014).

The African continent is known for lack of information on several environmental issues, including those related to biodiversity and ecosystem services (Egoh et al., 2012; Mayaux et al., 2004). The recent Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) regional assessment for Africa has highlighted gaps that exist in data and information on the continent to respond to policy goals such as those related to SDGs and the CBD (Mastrángelo et al., 2019; IPBES et al., 2018). Indeed, much of Africa is said to have poor proactive and reactive capacity to tackle the threat of IAS (Early et al., 2016). 2020 marks the end of the commitment period to the Aichi Biodiversity Targets. Now that the global community is gearing for the post-2020 Biodiversity Framework, it is opportune to take stock and identify opportunities to improve the performance of the African region beyond 2020. To the best of our knowledge, no Africa-wide studies exist that have collated evidence of impacts. In addition, while there is a myriad of studies and assessments of the ecology of IAS and the associated impacts on biodiversity, the same cannot be said for their impacts on ecosystem services, and ultimately on human well-being, particularly in Africa. There have been a few studies documenting the evidence of IAS impacts on ecosystem services across the world, however, these have focused on specific species and/or ecosystem types (Shackleton et al., 2014; Branco et al., 2015; Potgieter et al., 2019). Recent attempts at extending focus beyond certain taxa and/or the local scale (e.g. Castro-Díez et al., 2019; Shackleton et al., 2019) have not specifically dealt with the African region, nor collated and reviewed evidence from National Reports to the CBD in addition to peer-reviewed scientific literature. This study serves to fill that gap, for the purpose of supporting and improving evidence-based decisions on the management and regulation of IAS in Africa.

We reviewed literature and National Reports on the impact of IAS on ecosystem services in Africa by identifying: 1) *What ecosystem services are impacted by IAS; 2) What are some of the key IAS that have negative impacts on ecosystem services*; and *3) What expertise exists in Africa to provide scientific information needed to respond to the implementation of policies related to IAS*. This study should raise awareness on the impacts of IAS on ecosystem services on the continent and in specific countries and regions, and should feed into the upcoming IPBES thematic assessment on IAS. Most importantly, it should advise governments on the urgency of the problem and what strategies to put in place for the management of IAS, including building capacity within the continent.

2. Materials and methods

In this study we used two sources of information to document evidence of impacts of IAS on ecosystem services in Africa. These were, (i) National Reports submitted to the CBD by individual countries; and (ii) peer-reviewed scientific literature from both SCOPUS and Web of Science. We also assessed the expertise in Africa on invasion biology based on the literature reviewed.

2.1. Review procedure

2.1.1. National Reports to the Convention on Biological Diversity (CBD)

According to Article 26 of the CBD, National Reports are the principal instruments for reporting on measures taken to implement the provisions of the CBD, and their effectiveness in meeting its objectives. Essentially, National Reports serve as progress reports for the implementation of NBSAPs. Many African countries now have NBSAPs in place, and submit periodic National Reports to the CBD. We considered all African countries but only found National Reports for 48 countries when we searched the CBD repository (https://www.cbd.int/reports). From these 48 reports, we extracted information on the ecosystem services reported as being impacted by IASand its taxonomic group. Despite the existence of initiatives such as the Centre for Agriculture and Bioscience International (CABI, https://www.cabi.org) and work done by IUCN, we chose the National Reports with an assumption that all work done in a country will be presented in the National Report, given the reporting commitment to CBD. In addition, all African countries are signatory to the CBD, making results more comprehensive and comparable.

2.1.2. Peer-reviewed scientific literature

We conducted a search in SCOPUS with the keywords "invasive species" OR "exotic species" OR "alien" AND "ecosystem services". We did not have any time limit or restrictions to our search. The search was carried out in October 2018. We excluded all non-African countries using the exclusion criteria within SCOPUS. We did the same search in Web of Science and followed the same procedure. We merged the outcome of the two searches and removed duplicates. We went further in Web of Science to do a country-specific search using the same keywords but adding the specific country (e.g. Algeria). We read the abstracts of all papers we found (54), but only read in full and included papers that dealt with the impacts of IAS on ecosystem services. When there were several studies from the same author, in the same study area, about the same ecosystem service, we only included one study. We ended up with 36 studies. For each of the 36 studies, we extracted information such as the study area, scale of study, the ecosystem service impacted, IAS listed as causing impacts and the country of first author affiliation as well as the country where the study was carried out.

3. Results

Of the 48 National Reports reviewed, 35 (73%) had reported impacts of IAS on ecosystem services. The top four ecosystem services reported by countries included fish provision (53%), agricultural productivity (34%), grazing (26%), water supply (24%) and water quality (13%) (Fig. 1(a)). Habitat provision and recreation were reported in at least 5% of the countries. When the National Reports were broken down into regions following the IPBES classification (North, East, Southern, West and Central Africa), we found that different services were important for different regions with some similarities across regions. For example, while fish provision came up as the most highly reported in all regions, grazing was reported mostly in southern and east Africa (Fig. 2). In the National Reports, provisioning services (material we collect from nature) were the most impacted in all the regions (Fig. 3) followed by regulating services (how nature regulates movement of substances). The same pattern was observed within the scientific literature where 3 of the top ecosystem services reported in National Reports were also reported in scientific literature. The ecosystem services most impacted by IAS as recorded in scientific literature were water supply (42), habitat provision (31%), grazing (31%) and fish production (14%) (Fig. 1(b)). These services are the most crucial when it comes to food security.

Although more than 70% of African countries had reported impact of IAS on ecosystem services spanning the period of 2004–2018, only 36 studies were found in the scientific literature with most of them being local studies (Fig. 4). There has been some increase in the number of scientific studies reporting impacts of IAS on ecosystem services in Africa with most of the studies carried out in 2017. While many scientific studies were published between 2009 and 2011, following the Millennium Ecosystem Assessment (MA) and the setting of the Aichi Biodiversity Targets in 2010, not many were carried out between 2011 and 2014. Two thirds of the studies included in this review were from South Africa (22), followed by Ethiopia (6) and Kenya (4). Other countries studied include Nigeria, Madagascar, Mauritius, Malawi, Uganda and Zimbabwe. However, most of the authors of these studies were not necessarily from Africa, except for the studies from South Africa (Table 1). While almost half of the first authors were from South African institutions, about 40% were not from Africa. These first authors were from institutions in USA, Germany, UK, Italy and Croatia who carried out studies in Africa. Only 8% of the studies were global studies which included Africa. Indeed, 47% of the studies were local studies.

More than 100 different IAS were reported in Africa, both in the National Reports and peer-reviewed scientific literature. The most common IAS reported in at least 21 countries (43%) was *Eichhornia crassipes* (Water hyacinth; Fig. 5(a)). *Lantana camara* L., *Chromolaena odorata* (L.), and *Prosopis juliflora* (Sw.) were among the most common species reported in 10 (20%), 7 (14%) and 6 (12%) countries respectively. In contrast, the most common species as reported in the peer-reviewed scientific literature were *Acacia* spp, including *Acacia mearnsii* (De Wild), A. *saligna* (Labill.), *A. melanoxylon* R. Br. and *A. dealbata* R. Br. amongst others. Other species commonly reported in the scientific literature include *Pinus*, *Eucalyptus* and *Cylindropuntia* spp (Fig. 5(b)). Both *Chromolaena odorata* and *Prosopis Spp* were reported as top species in both the National Reports and peer reviewed literature.

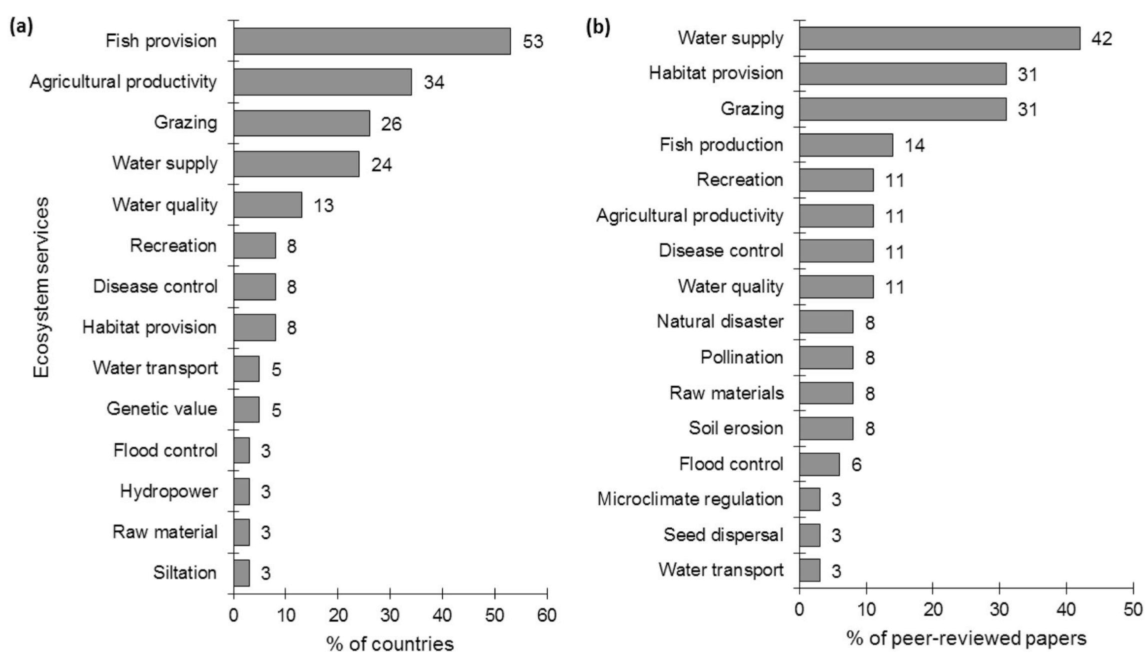

Fig. 1. Ecosystem services reported to be impacted by invasive alien plants: (a) Percentage of countries (National Reports) which reported negative impact of IAS on various ecosystem services., and (b) Percentage of peer-reviewed scientific literature.

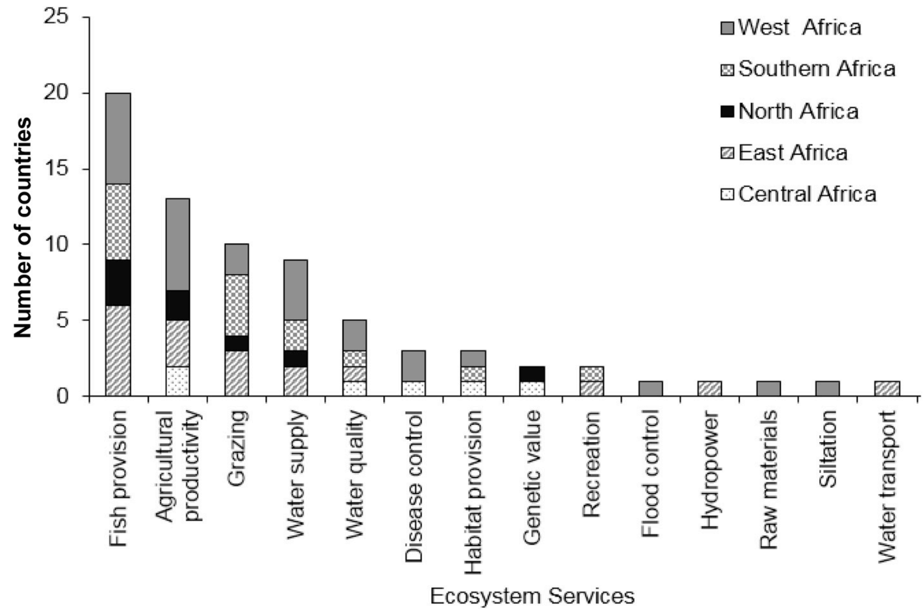

Fig. 2. Ecosystem services impacted per region in Africa according to National Reports.

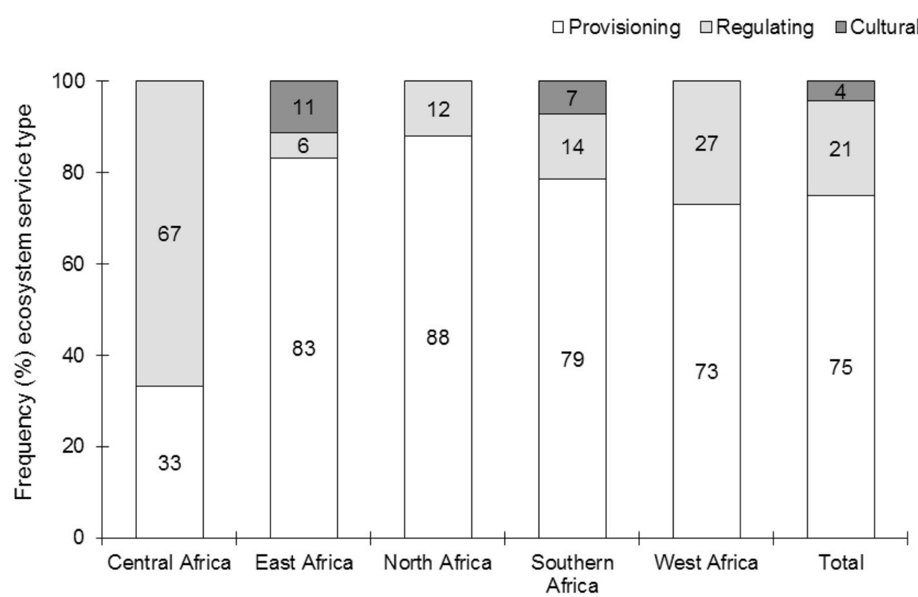

Fig. 3. Frequency (%) (N = 48) of ecosystem service types listed in the National Reports per region (adapted from TEEB classification).

4. Discussion

About 70% of African countries reported some kind of impact of IAS on ecosystem services in their national reporting for CBD Target 9. However, only few studies (36) from the scientific literature have looked at the impact of IAS on ecosystem services in Africa. Moreover, these studies are not evenly distributed across Africa, with more than half of them coming from South Africa alone. Sustainable ecosystem management, particularly in Africa, relies strongly on the acquisition and use of integrated systems of knowledge (Roux et al., 2006). For example, in South Africa, anecdotal information on the negative impacts of IAS on water resources, later confirmed by experimental research, has resulted in significant government support for the "*Working for Water*" (W*f*W) programme and its recognition as one of the biggest success stories of IAS control globally (van Wilgen et al., 1998; Zimmermann et al., 2004; Buch and Dixon, 2009). The evidence required to improve policy outcomes and facilitate management decisions in Africa must come from scientific information focused on improving the understanding on the current and potential spread of IAS (Rouget et al., 2004; Early et al., 2016; Thapa et al., 2018), as well as associated impacts on biodiversity and ecosystem services, suitable control measures, and the costs and benefits of controlling IAS (Borokoni and Babalola, 2012). These types of information will help policy makers to first allocate the resources needed and secondly focus resources and help managers with regards to where and how to implement measures on the ground. An example is the W*f*W program (stated above) where scientific information on IAS which have negative impacts on water quantity and quality help with the prioritization of areas to be cleared to improve water supply and provide jobs. To prioritise areas for management in programs such as the WfW, country level information on the most problematic IAS and associated impacts is needed.

National Reports give an indication of the level of understanding of

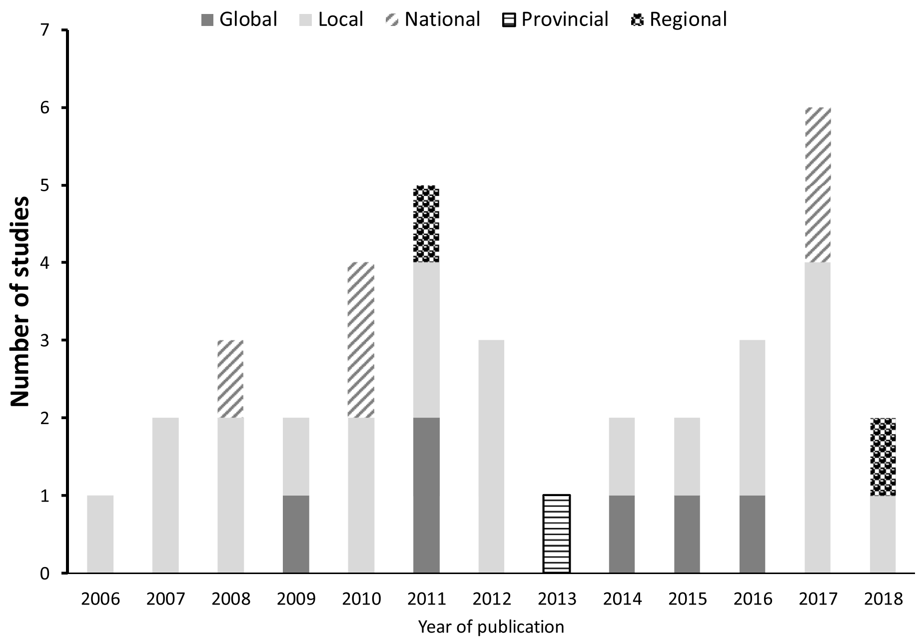

Fig. 4. Number of scientific articles (N = 36) on impacts of IAS in Africa included in the study and the scale at which they were carried.

Table 1
Summary of the nationality of first authors of reviewed scientific literature.

Country	Number of studies
South Africa	18
Nigeria	3
USA	3
Zimbabwe	2
Kenya	2
Australia	1
Bangladesh	1
Croatia	1
Germany	1
Ireland	1
Italy	1
Netherlands	1
Norway	1
Switzerland	1
UK	1

the IAS problem and potential response from countries. Indeed, the indicator for monitoring SDG 15.8 is listed as the proportion of countries adopting relevant national legislation and adequately resourcing the prevention or control of IAS. The significant impacts of IAS on ecosystems and their services, coupled with the lack of expertise on the continent, have the potential to undermine delivery on international targets such as Aichi and the SDGs. African countries cannot afford the additional investments needed to overcome these challenges. Results from this study show that there is a serious lack of expertise on the continent with few authors from Africa (except South Africa) publishing on the subject, despite the acknowledgement of impacts in the National Reports, which could jeopardize delivery on Aichi Biodiversity Target 9 and thus the effective management of IAS on the African continent. With the exception of South African studies, most of the scientific studies are primarily authored by experts from countries outside the African continent. Africa is lagging behind on expertise not only on IAS, but also on ecosystem services (Costanza and Kubiszewski, 2012). Analysis by Costanza and Kubiszewski (2012) of the authorship structure on the work on ecosystem services showed <10% of authors from Africa, all of them from South Africa. This aligns with findings from this study, where more than 50% of studies were from South Africa, being also the country with the highest number of first authors. In 2004, the National Research Foundation (NRF), the government body in charge of funding research in South Africa, in collaboration with national Department of Science and Innovation, through the DST-NRF Centres of Excellence Programme, recognised the need to build expertise and created arguably the only Centre of Excellence for Invasion Biology on the continent at Stellenbosch University (http://academic.sun.ac.za/cib/). This centre continues to train MSc and PhD students in the area of invasion biology and work closely with other institutions such as the Council for Scientific and Industrial Research (CSIR: www.csir.co.za) and the South African National Biodiversity Institute (SANBI, www.sanbi.org) to advance work in the field of invasion biology. Similar initiatives are urgently needed in other parts of Africa to advance the science that is needed to manage IAS on the continent.

The impact of IAS on ecosystem services has implication for food security and important livelihood aspects of people on the African continent and must be addressed urgently. Our results show an alignment between the National Reports and the scientific literature with water supply, agricultural production, grazing, habitat provision and fish production being one of the top ecosystem services identified as being impacted by IAS. More than 200 million Africans eat fish regularly, and fishing has been a central element of local economies in several African countries for many centuries (Béné and Heck, 2005). In West Africa, one of the regions with the highest reported cases of negative impacts on fish provision, the proportion of dietary protein that comes from fish is extremely high: 47% in Senegal, 62% in Gambia, and 63% in Sierra Leone and Ghana (Béné and Heck, 2005). Several studies have reported negative impacts of climate change on fish provision in Africa (Allison and Ellis, 2001; Allison et al., 2009). The compounded impacts of climate change and IAS could see many fish species going extinct locally, which will have serious impacts on the economies of African countries. According to Béné et al. (2009), fish is a “bank in the water” for chronic poor communities in Congo. The authors argue that small-scale fisheries can play a fundamental role in local economies, especially in remote rural areas where they strengthen significantly the livelihoods of people through their role in both food security and cash-income generation. Based on these findings, and previous research, the negative impacts of IAS on fish provision, does not only threaten food security for Africans, but threatens their livelihoods as well.

Similar to fish provision, agricultural productivity, grazing and water

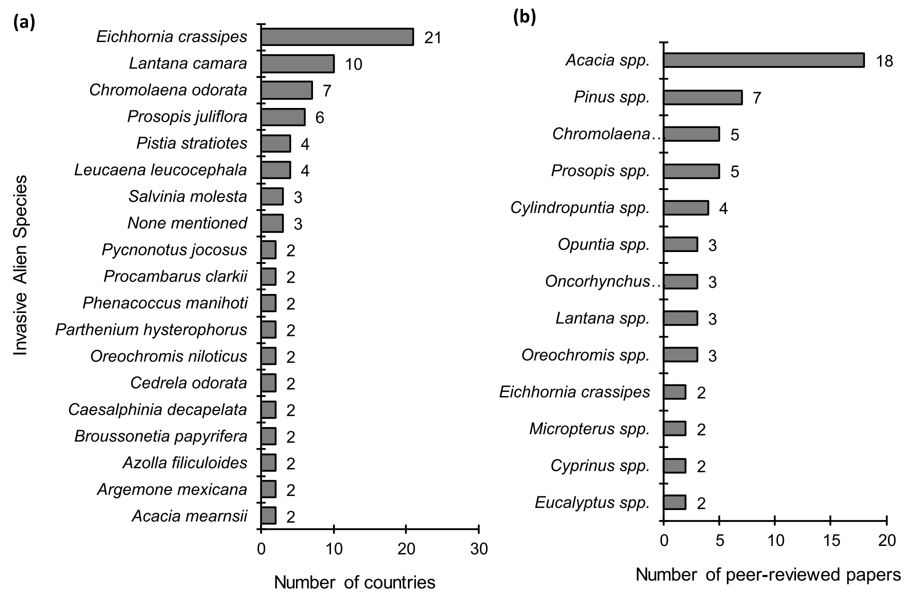

Fig. 5. Species mentioned to have negative impacts on ecosystems services in different countries from (a) National Reports (number of countries) and (b) Peer-reviewed scientific literature.

quantity and quality rank high as ecosystem services most impacted by IAS. Indeed, provisioning services associated with food provision were the most impacted services, followed by regulating services. For example, the cassava mealybug threatens the production of cassava, a staple food for many in Africa (Zeddies et al., 2001). In South Africa, several Acacia species negatively affect ecosystem services linked to the regulation of soil and water (Le Maitre et al., 2000). These results are supported by findings from Shackleton et al. (2019) who reported agricultural loss, grazing and water related services as one of the top ecosystem disservices in the world. These services are all linked to food security which is key in alleviating hunger and malnutrition on the continent, also critical to SDG 2 (Zero Hunger). Sub-Saharan Africa has one of the highest prevalence of hunger and malnutrition in the world (Sanchez and Swaminathan, 2005; Liu et al., 2008) where if impacts of IAS on provisioning services can be reduced will greatly benefit the livelihood of communities who depend on them for food and income (Shackleton et al., 2019). For example, although African countries are increasingly dependent on food imports to cover domestic needs, agriculture remains the largest economic sector in terms of state revenues as well as labour opportunities and livelihood provision (Rakotoarisoa et al., 2011; Buhaug et al., 2015). According to reports from Sudan, the bulk of mesquite (*Prosopis*) infestation (>90%) is in eastern Sudan where livestock keeping and subsistence cultivation constitute the main source of income. This invasive plant reduces grass cover, stocking density and threatens the livelihood of traditional pastoralists. However, despite the negative impacts posed by IAS, they (e.g. *Acacia* and *Prosopis*) are often introduced for their perceived benefits (Shackleton et al., 2007). These examples should serve as lessons for future introductions (Richardson and Blanchard, 2011).

Water quantity and quality are also important services not only linked to food security but an important service in most water scarce countries on the continent. Most countries in southern and northern Africa are water stressed, making water availability one of the most important resources on the continent. Water supply and other ecosystem services such as grazing highlighted in National Reports in this review are similar to those identified by government stakeholders in southern Africa as important for targeting land degradation neutrality investment in the region (Willemen et al., 2017). The ecosystem services most frequently identified as important by the stakeholders in all three countries (Tanzania, South Africa and Zambia) were those with a market value, a direct contribution to human well-being or have an important contribution to economic activities such as agriculture (e.g., food, fodder and water) (Willemen et al., 2017). Ecosystem services maps and maps on spread of IAS, can be used to prioritise areas for control if available but expertise in the field is needed.

Aside from understanding which ecosystem services are particularly impacted by IAS, it is important to acknowledge the species themselves. Our review shows that the IAS mentioned by National Reports as having the greatest impact are *Echhornia crassipes*, *Lantana camara*, *Chromolaena odorata* and *Prosopis* spp. These species are also listed as priority IAS in Africa by the CBD (https://www.cbd.int). According to Villamagna and Murphy (2010), *Echhornia crassipes* (water hyacinth), recorded in 21 countries (43%) in this review, is one of the world's most invasive aquatic plants that has invaded freshwater systems in over 50 countries on five continents and can alter biogeochemical processes in water bodies (Brendonck et al., 2003; Lowe et al., 2000). In Tanzania the invasion of lakes by water hyacinth is linked to the reduction of fish through deoxygenation of water and reduction of nutrients in sheltered bays which are breeding and nursery grounds for fish, particularly tilapia. Surprisingly, this IAS only appeared once in the 36 scientific studies reviewed and did not make the top species identified. Also, this was not one of the IAS studied in the recent study by Shackleton et al. (2019). There is an urgent need for scientific studies which identify the most problematic species including emerging IAS, their distribution, impacts on ecosystem services and links to livelihoods at local, national and continental scales. At present, the scientific studies from this review were mostly at the local scale. Policy implementation of control of IAS should happen at all scales including national, regional and continental scales.

5. Conclusion

All African countries have committed to reducing IAS in their national territories through global initiatives such as the CBD Aichi Biodiversity Targets, UNCCD and SDG. To meet these commitments, and to reduce the impacts of IAS on biodiversity and ecosystem services, information on the status-quo of the impact of IAS is needed. In this study, we have synthesized existing literature to better understand the impacts of IAS on ecosystem services in Africa and explored the implication for human well-being. The CBD National reports can provide important information and highlight potential gaps in scientific knowledge. Our findings suggests that many African countries may not have sufficient resources, expertise or data necessary to formulate and achieve targets aligned with Aichi Biodiversity Target 9. In addition, given the potential overlap in species and impacts between countries, it is important to establish systems to enable the sharing of knowledge and expertise across Africa to reduce the socio-economic and environmental impacts associated with IAS. While several online databases exist, such as those hosted by CABI and IUCN, increased support for scientific evidence and expertise is needed to support government action. IAS continues to be an important and serious issue and the CBD's post 2020 target could seek to improve regional collaboration to address issues. However, achieving any target related to IAS must be accompanied by building capacity on the continent to tackle such problems. It is not enough to assign these global targets without a target committing to building capacity or putting the resources needed to achieve it. These challenges which also relate to SDG need to be addressed starting with capacity building on the continent.

Declaration of competing interest

The declaration by the authors is that there is no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2020.110171.

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