An assessment of the capacity and responsiveness of a national system to address the threat of invasive species: a systems approach with examples from Kenya and Zambia

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Abstract

Background: Invasive species affect the social, economic and health aspects of many farmers and are known to cause major losses with considerable costs spent on management. Several international agreements recognise the threat caused by invasive species which signatories have an obligation to manage. This paper sets out a framework and method for assessing the performance and responsiveness of a country's invasive species system. The objective is to engage with key actors within an invasive species system using a participatory approach to determine the strengths, weaknesses and functioning of the invasive species system. The aim is to understand the system as it currently stands and to identify opportunities and challenges from various actor's perspectives.

Method: The first step was to define an invasive species system and its component parts including the functions, expected outputs and contextual factors. Subsequently,

a range of indicators and participatory tools were developed to measure system performance. The process includes a desk review, stakeholder workshop and key informant interviews. The approach was piloted in Kenya, but a revised approach, focussing on the desk review and key informant interviews, was used in Zambia.

Results: Actors who are actively engaged in managing invasive species were identified and engaged in both Kenya and Zambia. The assessment process provided insights into the current functioning of the invasive species systems in both countries. A number of key challenges were identified relevant to both countries, for instance, the lack of finance, governance and leadership were identified as major barriers to effective system performance, alongside the lack of a central coordinating body to guide invasive species management.

Conclusion: The systems approach developed helped in facilitating the engagement of key actors within a country's invasive species system. The actors performed a self-assessment of the current system status and determined what is required to move towards more effective management of invasive species. Participants responded positively to the framework and process developed, which contributed to developing ownership and clear steps forward towards a more pro-active, rather than reactive, approach in the management of invasive species.

Key words

Systems approach, invasive species system, self-assessment, responsiveness, Kenya, Zambia.

Background

Invasive alien species (IAS) are species that, with human assistance, arrive in a new area and cause damage to crops, livestock production and other economic activities; human health; and the environment. Only a small proportion of non-native species become invasive, but those that do cause major direct and indirect losses, including the substantial costs of managing them. Many international conventions recognise the threat from invasive species. For example, the International Plant Protection Convention (IPPC) aims to “protect cultivated and wild plants by preventing the introduction and spread of pests” and to protect “global plant resources from the introduction and spread of plant pests” (FAO, 2011). Parties to the 1992 Convention on Biological Diversity (CBD) agree in Article 8 (h) to “prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species” (UNEP, 2002). This means that signatories have a responsibility to manage invasive species, and in order to do that, countries first need to put the necessary capacity and an effective control structure in place.

Invasive species affect many sectors within a country e.g. agriculture, environment, human health, trade and water. Effective management of these species requires concerted efforts from the many different actors involved, whose functions and roles are complementary; no single organisation can manage invasive species in isolation. There should be linkages and relationships between the actors, so that they work together in their different roles to manage invasive species across the country. These actors, their roles, and the functions they provide are the building blocks of the system that needs to function as one unit.

The Convention on Biological Diversity (CBD) toolkit on invasive species aims “to empower CBD Parties to integrate the relevant standards, agreements, and guidance developed by other major international instruments into their National Invasive Species Strategies and Action Plans (NISSAPs) and the IAS components of the National Biodiversity Strategies and Action Plans (NBSAPs) [and] provide opportunities for governments to envision and enact a comprehensive approach to minimising the spread and impacts of IAS.” (CBD, 2011). Wittenberg and Cock (2001) provide a toolkit of IAS best prevention and management practices. Here, the necessary steps

towards building a strategy and policy, national commitment and institutional support in the prevention, early detection, and the assessment and management of IAS are outlined. They highlight the crucial step of identifying and involving all stakeholders prior to developing a national strategy, and the requirement of a single lead coordinating organisation, or if an inter-agency approach, clearly defined and allocated roles and responsibilities.

However, since there is no current definition of an invasive species system, examples of systems definitions were sought from other systems. For example, sanitary and phytosanitary (SPS) / crop protection systems have been described as a “collection of organisations and institutions” (CABI, 2011), that provide a number of services and functions that together deliver crop protection services. These services can be broken down into a number of different functions e.g. identification and diagnosis of pests, pest risk analysis, surveillance, and emergency preparedness (CABI, 2011) that have to be delivered in order for the system to be effective. Within SPS systems Day (2013) lists the component parts as: actors, functions, linkages, measures, policy and governance, and SPS standards and compliance. An agricultural innovation system (AIS) is defined as “a network of actors (individuals, organizations and enterprises), together with supporting institutions and policies in the agricultural and related sectors that bring existing or new products, processes, and forms of organization into social and economic use” (Tropical Agriculture Platform, 2016). Danielsen & Matsiko (2016) state that a “plant health system consists of all organisations, people and actions whose primary intent is to promote, restore or maintain plant health”. They note that for the system to achieve any outcomes there must be functioning linkages between the actors within the system. The common element in these definitions is that the systems consist of organisations and actors that deliver the functions of the system, as well as the linkages and relationships between the organisations and actors. Latham (2014) define these pathways as the “organisational and inter-organisational arrangements” that enable a system to deliver its aims and outcomes. Latham (2014) also includes laws, policies and regulations as part of the institutional structures of the system. FAO and CIRAD (2018) note that agricultural innovation systems consist of “multiple linkages” as well as relationships and knowledge flow between actors. They

also state that AIS evolve and that interactions between actors have to be considered as well as the functions themselves.

Attempts have been made to evaluate other systems such as SPS, AIS and plant and human health systems. Within the SPS field, the Inter-American Institute for Cooperation on Agriculture (IICA), have developed a Performance, Vision and Strategy (PVS) measurement tool for National Plant Protection Organisations (NPPOs). The tool aims to help countries strengthen their NPPOs through identifying strengths, weaknesses and developing strategies to increase capacity (IICA, 2015). The tool breaks down the function of the NPPO into four components with 28 critical competencies. In order to measure these critical competencies, the competency is defined and then five levels of progress to achieving that 'definition' are described. The country is then able to decide which level of progress most accurately reflects their existing status, and through this, a score is obtained for each competency. The PVS tool complements other SPS measurement tools, such as the Phytosanitary Capacity Evaluation (PCE) tool (IICA, 2015), developed by the IPPC. This was developed to assess the capacity of NPPOs to implement the International Standards for Phytosanitary Measures (ISPMs) *(*Day *et al*., 2006).

Assessments of AIS have taken a more participatory approach, with objectives that provide recommendations, support policy makers, and support collective action to strengthen and improve AIS (FAO and CIRAD, 2018). The approach aims to build consensus with the system actors about the strengths and weaknesses of the system, and to identify interventions that can strengthen the system. It also notes that qualitative and quantitative methods should be used in a participatory manner with stakeholders from across the system (e.g. farmers, non-governmental organisations (NGOs), researchers and policy makers), to assess both structural (e.g. actor mapping) and functional (e.g. knowledge flow) knowledge, in combination with secondary data. The method acknowledges that indicators are needed, but notes that these indicators will depend on the way the assessment is being carried out, as well as the context of the assessment. A final point within this assessment framework is the need to consider the linkages and interrelationships between actors, regardless of which function or domain they are considered to be part of (FAO and CIRAD, 2018).

This paper sets out an approach to assessing the current status, performance levels and responsiveness of an invasive species system within a country. The aim of the approach is to facilitate the evaluation of the invasive species system. The objective is to engage with key actors from various backgrounds and levels of responsibility active within the invasive species system in a country using a participatory approach and a range of clearly defined and specific indicators to determine the strengths, weaknesses and functioning of the invasive species system. The aim is to understand the system as it currently stands and to identify opportunities and challenges from various actors' perspectives. For countries that already have a NISSAP, the findings can support its implementation, as well as supporting the relevant part of the country's NBSAP. For countries without a NISSAP, the results of the approach we present would provide a good basis for developing a NISSAP. The approach also complements the use and implementation of toolkits that have been developed for the prevention and management of IAS (FAO, 2007; IUCN, 2000, 2018; Wittenberg & Cock, 2001).

Methods

A methodology for describing and evaluating the capacity and performance of a country in responding to the threat of invasive species was developed. First, an invasive species system and its component parts are defined. Second, a method is developed to understand the structure of a system (organisations and their mandates, policy, regulation etc.), as well as indicators to measure the system's current perceived performance. The method was first tested in Kenya, where actors within the system undertook a participatory assessment, and generated a forward plan to strengthen the invasive species system within the country. The method can also act as a baseline against which a later application of the same method would enable documentation of changes in responsiveness. Although it was intended to use the approach in Zambia it had to be adapted due to Covid-19. We discuss the value of the proposed approach to assessing the current status and functioning of an invasive species system and consider the depth of information it was possible to collect under the different circumstances.

Framing the invasive species system

We explored systems approaches (for example, plant health systems and agricultural innovation systems) and how these systems had been defined, structured, regulated and what elements were assessed when considering their performance. Searches were done both in published and grey literature, and through sources who worked in the systems areas mentioned above. There are various instruments and institutions identified as important in IAS management as listed in the CBD toolkit (2011), as well as the requirement of country NISSAPs to identify actors, their mandates and responsibilities regarding invasive species. However, this research led to a recognition that there is no current definition of an invasive species system on which to base any sort of assessment system and, accordingly, no defined assessment system. We therefore define what an invasive species system is, as well as its component parts as the basis for an assessment system. These are described in the following sections.

System definition

We define an invasive species system as follows:

An invasive species system consists of all organisations, people and actions whose intent is to combat the threat, spread and effects of invasive species.

In order to make this definition more meaningful the building blocks of the system need defining as do the functions and outputs that should be delivered; the actors involved; and the context in which the system operates.

Components of an invasive species system

Based on the components described in the literature for other systems (Danielsen & Matsiko, 2016; IUCN, 2000, 2018; Williams *et al*., 2015; Wittenberg & Cock, 2001) we identified a number of key components and functions important in an invasive species system. Also noting that system delivery is dependent on contextual factors including staffing, governance and leadership, finance and communications (Figure 1). Some functions are relevant to specific overarching outputs (for example, risk analysis to prevention and quarantine to prevention and detection) whereas other functions are more cross-cutting (for example, research and technology and policy and regulation) (Table 1).

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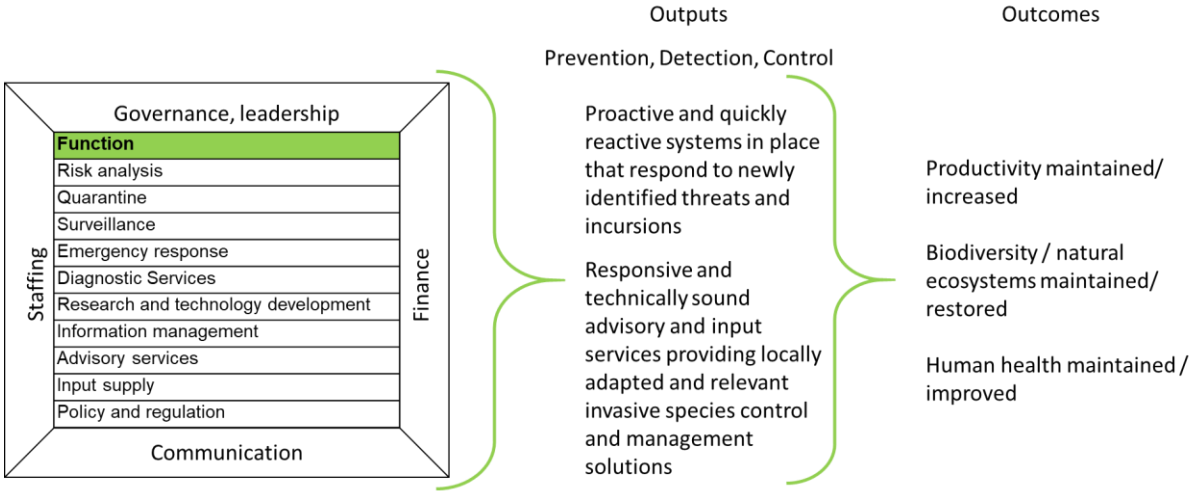
221 **Figure 1: Invasive species system components**



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223 Based on Danielsen and Matsiko, 2016; CABI, 2018

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225 **Table 1: System functions and outcomes**

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System function	**Outcome in a functioning system**	***Contribution to overarching outputs***
Risk analysis System for evaluation of potential pests and invasive species	Comprehensive and timely analysis of potential invasive species carried out and reported to relevant authorities	Prevention
Surveillance Monitoring and reporting procedures and system	Rapid knowledge and identification of existing invasive and pest outbreaks; new invasive and pest species; and high-risk species reported to relevant authorities	Detection / Early Detection and Rapid Response
Quarantine Procedures, disposal and housing facilities to contain and isolate organisms from the outside environment	Few or no incursions of identified high-risk invasive species	Prevention and detection
Emergency response Knowledge, information and procedures necessary for rapid response to invasive species/pest outbreaks	Spread of pest/invasive species restricted through quick implementation of: eradication measures, control of movement of people, vehicles, equipment, planting material; containment measures; restricted access	Eradication and containment
Diagnostic services Diagnostic knowledge, facilities and procedures, including referral systems	Timely and accurate identification of unknown pests and invasive species reported to relevant authorities	Cross cutting
Research and technology development	Development of relevant management practices and technologies for invasive	Cross cutting

Research knowledge and facilities	species when required, that are feasible and affordable for farmers and other land users to implement	
Information management Extension and information materials, databases, species lists etc.	Timely creation and management of invasive species information for system stakeholders to increase knowledge and support decision making	Cross cutting
Advisory services Agricultural extension, mass media, pest alerts, other dissemination mechanisms	Delivery of advice on invasive species, including pests, to land users, covering alerts and management options. Advice should be accessible to all who need the information, when they need it, in suitable formats	Cross cutting
Input supply Supply of seeds, fertiliser, pesticides, monitoring equipment, biopesticides including biocontrol products etc.	Inputs for land and farm management available when needed, at an affordable price, and meeting quality and safety standards	Control and management (short and longer term)
Policy and regulation Laws, policies and regulation relating to plant protection, movement of animals and plants, quarantine, surveillance, risk analysis, input registration and certification etc.	Laws, policies and regulations enacted, implemented and enforced, providing guidance and a framework for the invasive species system	Cross cutting

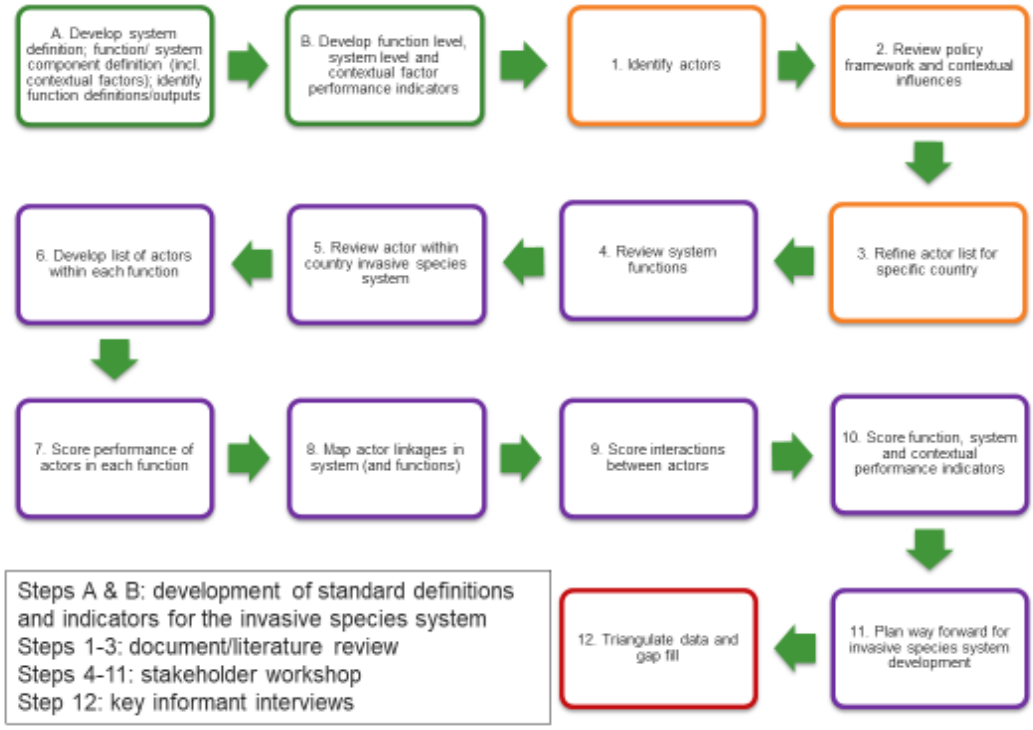
In addition to understanding the functions, we have to know what actors are involved in delivering each of these functions, as it is through the actors and the linkages and relationships between them, that the outputs of the functions will depend and be delivered (Danielsen and Matsiko, 2016). However as noted by FAO and CIRAD (2018), the actors within each function are dependent on the context in which the system is operating. The actors will therefore vary by country, and so defining the actors within each function becomes part of the assessment process itself.

Assessment process

The approaches outlined for other systems e.g. IICA, 2015; FAO and CIRAD, 2018 indicate that a combination of qualitative and quantitative techniques is the most appropriate method to assess the performance of a system. Figure 2 illustrates the steps taken in the assessment process which is described below. Steps A & B consist of the overarching system definitions and indicators developed and presented in this

study. The following steps are applicable to the specific system assessment within a country which consists of three main components: 1. Document/literature review; 2. Stakeholder workshop; and 3. Key informant interviews (KIIs). We tested the approach in Kenya, where CABI has a regional office with links to various organisations (government, non-government, private etc.), research institutes and individuals working on invasive species. Williams & Constantine (2019) provides a comprehensive account of the method and approach.

Figure 2: Summary of assessment method



Document review

We started the assessment process with a literature review to provide a general understanding of the system and its functioning within Kenya. We identified the key actors in invasive species management delivery, what approaches are used, and what human and financial resources are available. We reviewed policies relevant to agriculture, environment and invasive species, as well as general policies, e.g. on governance structures and institutional mandates, that determine how policies are implemented. We considered information that related to contextual influences, such as institutional structures and histories; donor influences, politics and organisational

culture, and other relevant documents such as international, regional, central/local strategies, implementation plans and budgets, key statistics, evaluation reports etc.

This information, and the function outputs defined in Table 1, provided sufficient information to be able to establish which actors were involved in each function. Five function-level indicators were then defined and one system-level indicator (Table 2) to assess how the functions deliver their outputs as a whole, and how the system as a whole performs against its outcomes as defined in Figure 1, using the more qualitative criteria from Latham (2014), Danielsen and Matsiko (2016), and Sharma *et al* (2017). Key contextual factors were also defined (Table 2) in order to be able to assess whether they enabled functions to deliver their outputs, or were a barrier to function and system delivery (see Additional files, Tables A & B for all indicators).

Table 2: Function and system-level performance indicators

Function-level indicator	**General definition**
Availability and access	How many users are making use of the output of the function? Are all groups able to obtain the function output they require at their convenience? Are certain groups excluded because of gender, ethnicity, literacy level, socio-economic status, distance, etc.?
Acceptability	Is the output of the function relevant, effective and appropriate and of the required quality? Is it the correct solution to the issue?
Timeliness	Is the function output delivered when required by the user without unnecessary delays?
Affordability	Is the output of the function available at an acceptable price for users? Do users perceive it is good value for money?
Sustainability	Is the function self-sustaining and able to deliver its output without external support?
System-level indicator	
Coherence	To what extent does the system work in a logical and consistent manner, and form a unified whole?
Contextual factors	
Finance	Does each function have sufficient monetary resources to fulfil its mandate?

Staffing	Does each function have sufficient staff with sufficient knowledge and expertise to fulfil its mandate?
Governance, leadership	Does the governance and leadership of each function enable it to fulfil its mandate?
Communication	Do the different functions within the system communicate with each other to deliver an effective invasive species system?

We recognised that official policy and institutional arrangements do not always reflect reality on the ground. Therefore, while the document review is a good entry point to start to understand the system, the workshop provided an understanding of what is actually happening within Kenya.

Stakeholder workshop

The purpose of the workshop was to assess the current functioning of the invasive species system, who is involved, how they interact and how they deliver their mandates within the system. The workshop was held in Nakuru, Kenya from 25th to 27th September 2019. Based on the document review, twenty-four actors were identified to invite to the workshop, ensuring that there were both central and local-level representatives, and representatives from different levels of seniority so that those present included people who understood both the policy and practitioner levels. The workshop ran for 2.5 days, with a series of group and plenary sessions, and the final session focused on forward planning and how to address the key challenges identified in the workshop. A detailed workshop guide is given in Williams and Constantine (2019). A summary of the key steps and activities held during the workshop is provided in Table 3, alongside detail on data analysis, where this was required. Throughout the workshop participants were requested to ensure the indicators or scores reflected the systems current performance and not what should be happening if the system and its components parts were functioning ideally.

Table 3: Key steps and activities in the stakeholder workshop

Key steps	**Detail on activity**

Invasive species system functions	Participants discussed function definitions (Table 1) and whether they agreed with the functions being divided in this manner, and if definitions were suitable.
Actors in the invasive species system	The actor list (Table 4) generated through the desk review was presented and discussed. Participants were asked to identify if any actors were missing, needed breaking down into smaller groupings or combining to form a larger overall actor. This exercise ensured everyone referred to the actors in the same way throughout the workshop.
Actors within each invasive species system function	The actors within each function were discussed based on pre-prepared lists (Table 5). Separate lists were shared for each function, which the facilitator added to as participants identified additional actors.
Actor scoring within functions[1]	In groups participants scored each actor's performance within each function against predetermined indicators (on a scale of one to five) (Supplementary Information Table A). Group scores were then discussed and challenged, as necessary in a plenary session. For analysis the average score for each function (across all actors) and for each actor (across functions) were calculated.
Actor mapping within the system (Qualitative tool providing the first assessment of the system in its entirety)	Participants considered how the actors worked and interacted together. In smaller groups they drew a map of which actors talked to which other actors and whether the relationship was one way (i.e. top down) or truly interactive. Groups presented their maps back to all the participants for discussion. The exercise provided an overall picture of the complexities that are often intrinsic in such systems.
Interaction scoring[2] (Complementary to the maps, a quantitative assessment of actor interactions)	Participants ranked each actor-to-actor interaction on a scale of zero to four, with zero being no interaction, even though there should be, and four being a very strong interaction. Discussions around each score focused on whether there was information and knowledge exchange between the actors, the level of coordination and feedback and whether any financial mechanisms were involved. In a number of instances, two

	groups provided scores for interactions between the same two actors; in these cases, an average score was considered and reported.
Invasive species system indicator performance scoring[3]	Assessment of how each function as a whole performed against the defined performance indicators (Supplementary Information Table B). Participants rated each function against the performance indicators described, providing a quantitative score for each function as well as system-level performance indicators and the contextual factors. The group scores were discussed in plenary to reach a consensus in assessment of the system performance.
Planning a way forward	The final session of the workshop focused on reviewing the findings so far, and based on these findings, planning a way forward. The participants identified the key issues that came out of the workshop, and current actions that were being taken. They also developed concrete plans to start to address the key issues identified.

[1,2,3] Supplementary Tables A and B provide specific indicators however, in general the indicator scores for [1] and [3] are equivalent to: 1 = no or very limited delivery of responsibilities; 2 = some delivery of responsibilities; 3 = average delivery of responsibilities; 4 = strong delivery of responsibilities; and 5 = very strong delivery of responsibilities. Interaction scores for [2] are 0 = no interaction (but there should be interaction); 1 = weak interaction; 2 = average interaction; 3 = strong interaction; and 4 = very strong interaction.

The data collected from the Kenyan study purposefully included a high amount of qualitative data. Where participants were asked to select a score representing an indicator, it was essential that the discussions around the scoring were captured. Therefore, throughout the workshop, facilitators took notes on participant discussions and comments, making enquiries if any information needed clarification.

Key informant interviews (KIIs)

The workshop provided considerable information as to how the invasive species system is functioning in Kenya. However, inevitably there were areas that were under-represented, unclear or even contradictory to the workshop findings. There were also

actors that were unable to attend e.g. Kenya Wildlife Service (KWS), and so their views and opinions were not represented. Therefore, four KIIs were conducted with: Agricultural and Food Authority (AFA), KWS, Ministry of Environment and Forestry, and the Joint Agriculture Sector Consultation and Cooperation Mechanism (JASCOM) to gap fill and identify important, and sometimes controversial, aspects and details that were not revealed in the workshop. The KIIs also helped to capture additional information about contextual influences such as the policy environment, institutional structures, donor influence, politics and organisational culture. Finally, the KIIs were used to verify and triangulate the information collected from the workshop and literature. Facilitators from the workshop carried out the KIIs to ensure that the knowledge from the workshop was used to tailor the questions being asked.

Assessing the invasive species systems in Zambia

Plans to use this method in Zambia in 2020 were affected by the Covid-19 pandemic and global travel and meeting restrictions. Therefore, a modified approach concentrating on the literature/ document review and comprehensive key informant interviews was adopted. The Zambia study took place during October and November 2020. The literature/ document review followed the same protocol described for Kenya. The process helped identify seventeen key actors in the invasive species system in Zambia with whom preliminary interviews were conducted. Following these preliminary interviews, a comprehensive checklist of key questions (Additional file 1) were sent to these representatives to complete and return. Once the checklists were returned, KIIs were conducted with stakeholders where it was identified that an actor could provide greater depth of information and insight. Here, the KIIs were relied on to help capture additional information about contextual influences such as policy environment, institutional structures, donor influence, politics and organisational culture.

Results

The aim of the work in Kenya was two-fold: to assess the current state of the Kenyan invasive species system, and to test the assessment approach and tools used. For Zambia, the results report on the current state of the invasive species system using a revised approach in the absence of the stakeholder workshop. The approach is

discussed to establish whether this was a suitable method to evaluate the current status of an invasive species system in a country.

Findings concerning the invasive species system in Kenya

Invasive species system functions

Discussions on the 10 pre-defined functions (Table 1) confirmed that participants thought these functions were accurate and appropriate. However, they highlighted that co-ordination and network provision for the invasive species system was not listed in the current functions but has a central role in the management/mitigation response to an invasive species threat by providing a leading role and focal point. In addition, they thought that the functions were largely reactive rather than proactive in tackling invasive species.

Actors in the invasive species system

The discussions around who is involved in the invasive species system in Kenya led to agreement on the principle actors identified before the workshop, as well as additional actors (Table 4). Examples of principle actors specific to Kenya include the Kenyan Plant Health Inspectorate Service (KEPHIS) as the NPPO, Kenya Agriculture and Livestock Research Organisation (KALRO) and Kenya Forestry Research Institute (KEFRI) as key research organisations, and the National Environment Management Authority (NEMA) as the environmental protection agency. Participants also clarified where certain actors fit into the system and under what 'group' they belonged. For example: land users/managers include the Kenya Wildlife Service and Kenya Forest Service (e.g. conservancies running protected areas and managing land where the priority is conservation rather than food production); legislators and policy makers include the Council of Governors/County Governments/Kenya Institute for Public Policy Research and Analysis (KIPPRA); and the Crop Development Board, which is now AFA, who governs all the crop boards (e.g. tea, coffee, sugarcane etc.).

Table 4: Actors within an invasive species system

Policy	Farming business	Land/aquatic management
• Legislators, policy makers • Ministry of Agriculture • Ministry of Environment	• Farmers • Farmer organisations • Community-based organisations	• Forestry dept • Fisheries dept • Environmental protection agency

• Ministry of Trade • *(Ministry of Foreign Affairs)** • *(Ministry of Education)* • *(Ministry of Finance, Revenue Authority)*	• Agro-dealers (village shops) • Agro-input suppliers/ import companies (suppliers of village shops, importers of pesticides etc.) • Extension department	• Land users/managers e.g. national park authorities, conservation area managers • Climate Change Secretariat
Trade • Traders (farm gate to market) • Transporters (farm gate to market) • Farm produce export companies	Research • National universities, research institutes and museums • International orgs – e.g. CABI, FAO, *icipe* and IPPC • Diagnostic labs • Crop development boards	Regulation • Regulators e.g. NPPO • Pesticide control body • Ministry of Health (Port Health, Public Health) • *(Ministry of Interior/Police)*
NGOs • Environmental • Humanitarian	Media • TV • Radio • Print media • Journalists	*Development organisations* • *World Bank* • *Africa Development Bank etc*

* Actors in italics were not part of the Kenya assessment process

Participants pointed out that there is lack of a coordination on invasive species management, and that they needed clarification of each institutions' mandates in order to fully understand their focus and responsibilities. Participants highlighted other actors that have a role in an invasive species system, but recognised that these actors were not critical or central to the system. These included humanitarian relief agencies and prisons, as the Ministry of Internal Security conduct farming, production and processing activities on large land areas and there is the potential to utilise this prison manpower e.g. for control purposes in the instance of an invasive pest outbreak and/or use large areas of land for control method trials.

Discussions around the different actors' roles in each function (Table 5) centred around actors' roles in risk analysis, emergency response, diagnostic services and information management. Participants thought that there is a reliance on KEPHIS to carry out risk analysis as the government arm that mostly deals with this on a regular basis. KALRO, *ICIPE*, KWS and the National Museums of Kenya (NMK) may carry out some risk analysis, but overall, the function is fragmented and not coordinated in the system with many working in isolation with very weak information sharing capacity.

Although many research institutions and government agencies have policies on data sharing, they are not always followed, and sometimes data sharing is actively discouraged. It was highlighted that unless the actors are working on a collaborative project it is very hard to know who to talk to. Participants noted that no one institution has the responsibility of declaring whether an 'invasion' is an emergency needing urgent attention. Moreover, emergency response needs coordination which is currently missing.

A number of different organisations offer diagnostic services such as NMK, private companies and research organisations (such as KALRO and KEFRI) but there is no national-level guide to various institutions on where hard to identify cases should be sent. There is no one-stop-shop for information on invasive species and participants expressed concern about the issue of retaining extension officers' knowledge due to devolution and extension officers' retirement. ICTs were seen as a good avenue to reach farmers with information on invasive species, and farmers currently receive a good amount of information through the media. For example, the local media houses have independent television for farmers e.g. KTN Farmers, while others have dedicated programmes or newspaper pull-out editions e.g. Seed of Gold, from the Daily Nation.

Table 5: Actors involved in each function

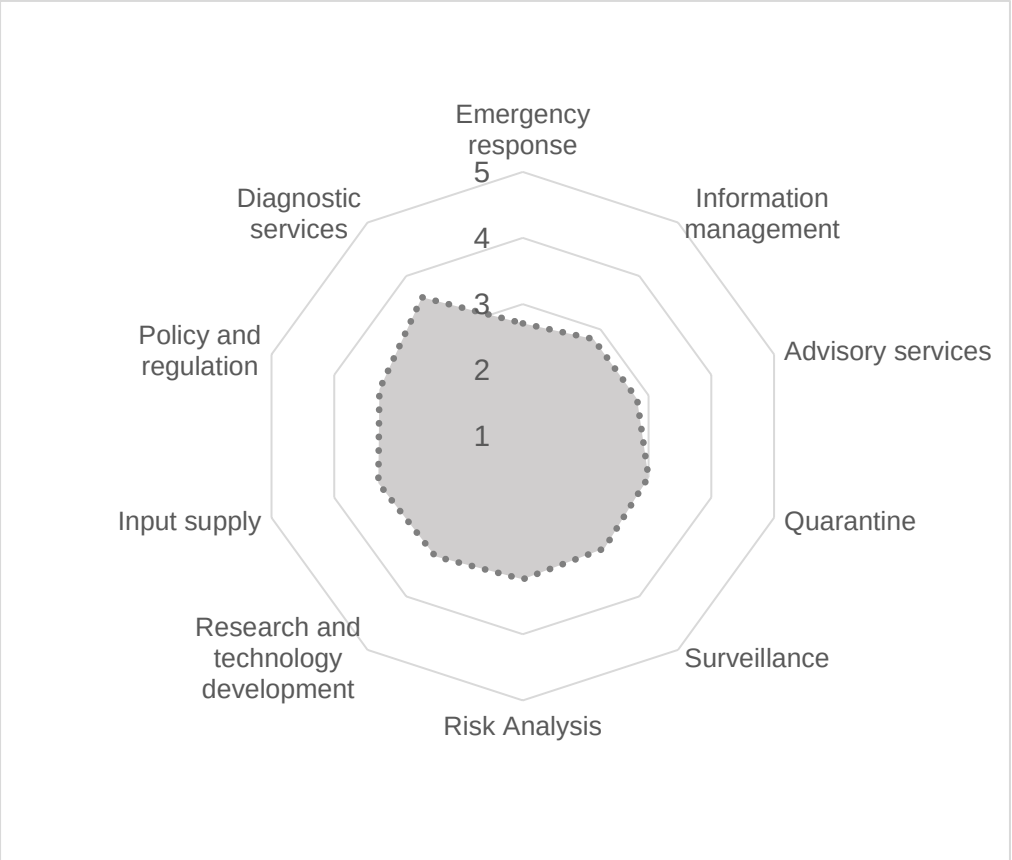
Actor	Function									
	Risk analysis	Quarantine	Surveillance	Emergency response	Diagnostic Services	Research/ technology development	Information management	Advisory services	Input supply	Policy and regulation
Legislators, policy makers				x						x
Ministry of Agriculture	x	x	x	x	x	x	x	x	x	x
Pesticide control body				x			x	x	x	
Crop development boards				x		x	x	x		
Regulators e.g. NPPO	x	x	x	x	x	x	x	x	x	x
Extension department			x	x			x	x	x	
Diagnostic labs					x	x	x			x
Farmers			x	x				x	x	
Farmer organisations			x	x			x	x	x	
Ministry of Environment	x	x	x	x			x	x		x
Environmental protection agency	x	x	x	x	x		x	x		x
Land users/managers			x	x		x		x	x	
Climate change secretariat	x						x	x		

Forestry dept, e.g. Kenya Forestry Service (KFS)	x	x	x	x	x	x	x			x
Fisheries dept	x	x	x	x	x	x	x			x
NGOs			x	x			x	x	x	
Community-based organisations			x	x			x	x	x	
National universities/research institutes	x	x	x	x	x	x	x	x	x	x
International organisations e.g. CABI, FAO and IPPC	x	x		x			x			x
Media				x			x			
Ministry of Health	x		x	x						
Agro-dealers (village level)				x				x	x	
Agro-input suppliers		x		x					x	
Export companies			x	x						
Ministry of Trade		x	x						x	x
Traders				x						
Transporters				x						

Actor scoring within functions

The workshop concluded that most of the actors were currently performing at approximately the level 3 indicator, suggesting that these actors have some awareness of the need to manage invasive species (see Additional file Table C for individual actor function scores, and Additional file Table D for detail of the participant discussions around the scoring). Although the system in Kenya has some strengths, there is significant room for improvement. Some functions were identified as operating slightly above average, for example, diagnostic services, whereas others such as emergency response were perceived to be operating below average (Fig. 3).

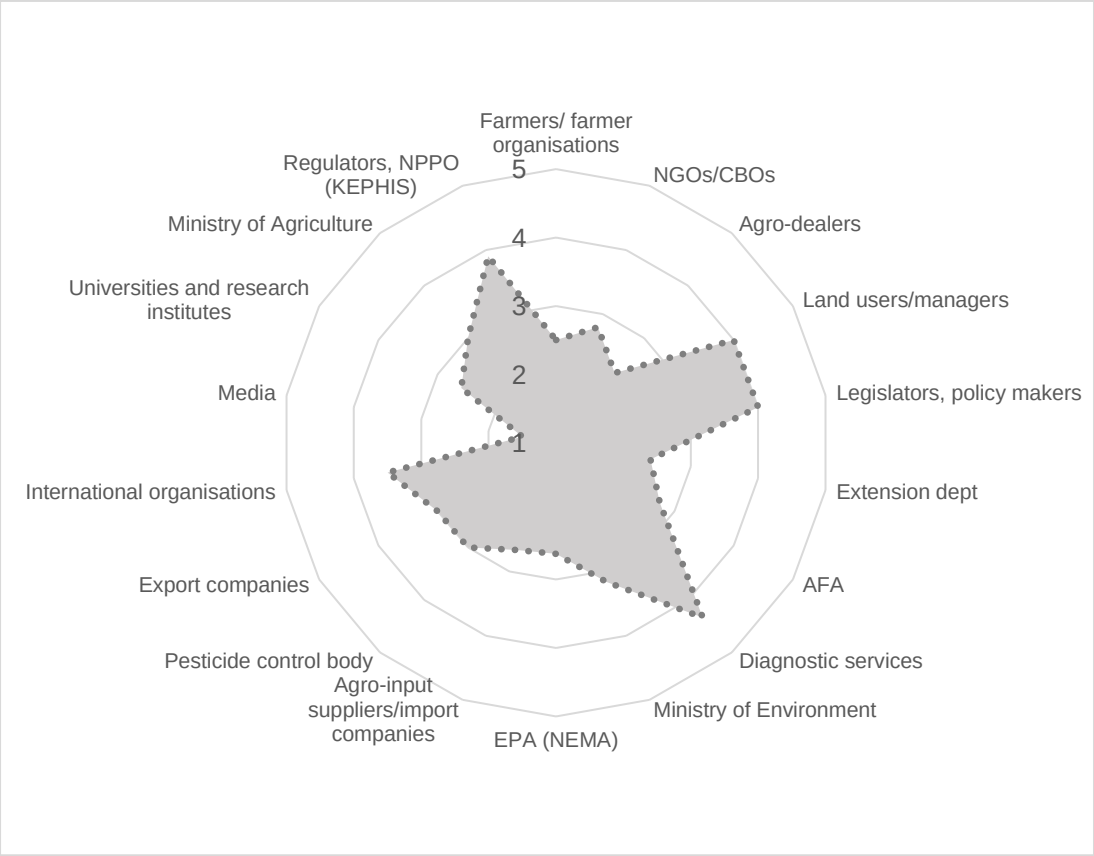
Figure 3: Average actor score for each function



Indicator scores: 1 = no or very limited delivery of responsibilities; 2 = some delivery of responsibilities; 3 = average delivery of responsibilities; 4 = strong delivery of responsibilities; and 5 = very strong delivery of responsibilities

The average actor scoring across functions indicates that most actors are delivering their work within each system function to some degree. However, some actors were perceived to be operating below average e.g. the media (involved in the functions of emergency response and information management). Diagnostic laboratories, on the other hand, were reported to be performing well above average (Fig. 4). There was a general consensus that more could be done, and there were areas of improvement across all functions and actors. In particular, participants identified networking and communication between stakeholders as an area that could be improved and which was considered a great opportunity for strengthening the system.

Figure 4: Average actor scores across all functions

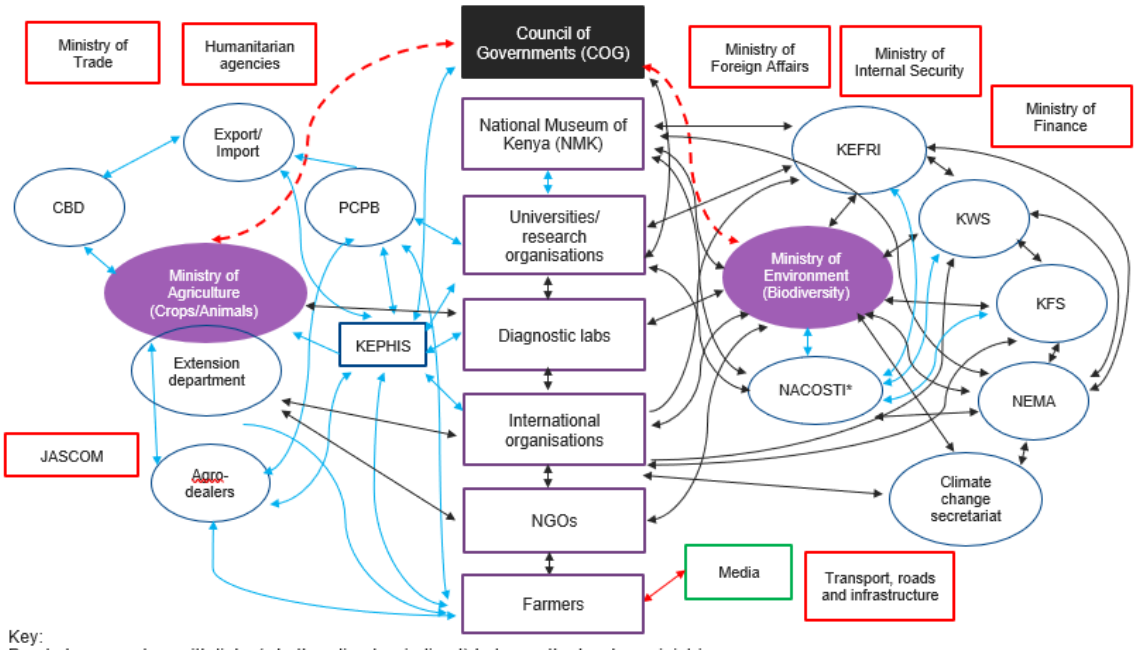


Indicator scores: 1 = no or very limited delivery of responsibilities; 2 = some delivery of responsibilities; 3 = average delivery of responsibilities; 4 = strong delivery of responsibilities; and 5 = very strong delivery of responsibilities

Actor mapping within system

The participating groups produced several different actor maps for the whole system. There was consensus that the system was very complex and that the complexities were best reflected in Fig. 5., which indicates that the Ministry of Agriculture, Livestock, Fisheries and Cooperatives (MoALF) and Ministry of Environment are the two key organisations in the system, although it was noted that the links between them are considered weak. The participants reported that farmers and biodiversity managers are also central to the system, and that farmers do have direct links with MoALF (via representatives of Kenya's National Farmers' Federation (KENAFF)). In addition, for some actors i.e. JASCOM, participants felt they did not know enough about the organisation to comment on their linkages.

Figure 5: Actor mapping



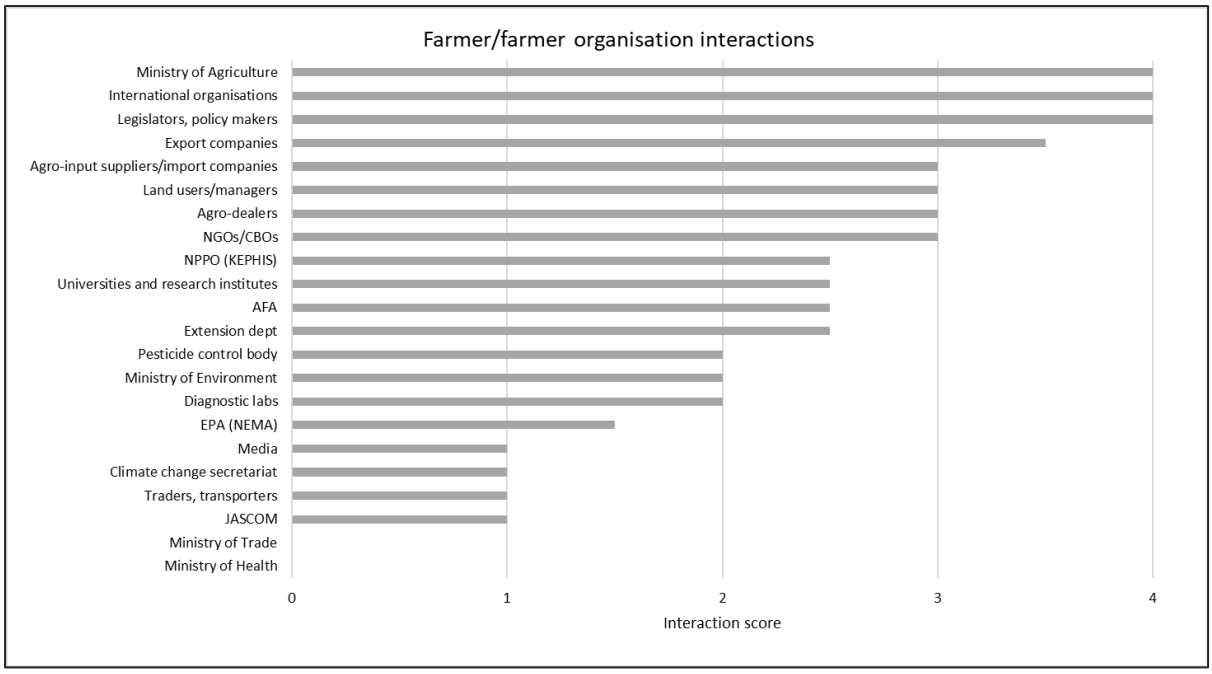
Participants noted that some ministries, e.g. the Ministry of Finance (recently renamed 'The National Treasury'), although currently not linked in the invasive species system, needs to be involved in any programme through its role in budget allocations. Budget policy makers need to be made aware of priority invasive species threats so that they can be influenced to allocate sufficient funds to relevant ministries and departments for the management of invasive species. However, the application and delivery of funds would be carried out by the other relevant ministries e.g. Ministry of Agriculture and Ministry of Environment.

Actor interaction scoring

Building on the linkages identified in the actor mapping, participants classed the level of interaction, stating that in a number of instances, there were either no interactions (where there should be one) or there was a weak interaction between actors on invasive species issues (see Additional file Table E and Additional file Table F). For example, traders and transporters received a score of zero for eight interactions with other actors. Many interactions were thought to be average i.e. the actors are

interacting but there is quite a lot of room for improvement. Fig. 6 shows an example of farmer/farmer organisation interaction scores.

Figure 6: Example of average scores participants allocated to farmer/farmer organisations' interactions with other actors



Interaction scores: 0 = no interaction (but there should be interaction); 1 = weak interaction; 2 = average interaction; 3 = strong interaction; and 4 = very strong interaction

Some interactions were thought to be strong, such as between land users/managers and legislators/policy makers, the extension department and AFA, and the Ministry of Agriculture and the Pest Control Product Board (PCPB). On the other hand, participants noted that in general, there has been little interaction on invasive species in the country. In cases where interactions were taking place these were often on general issues and not specific to invasive species.

Invasive species system indicator performance scoring

Results of the participants' assessment of overall system performance indicate that the invasive species system in Kenya is currently operating at approximately the indicator two level (Table 6). Some aspects of the system are operating above this level e.g. a score of four was reported for advisory services for both affordability and acceptability; input supply for acceptability; and information management for affordability. However, other parts of the system were considered to be operating at a

lower level e.g. for policy and regulation an indicator score of one was reported for both availability and timeliness. As a whole, participants considered that the invasive species system in Kenya is operating, but much needs to be improved before it could be considered to be optimal.

Table 6: System performance scoring by four system performance indicators

	Performance indicator				Contextual factors			
System functions	Availability, access, coverage	Accept-ability	Timeliness	Afford-ability	Finance	Staffing	Governance	Commun-ication
Risk analysis	-	3	2	-	B2	B1	B2	B2
Quarantine	2	3	2	3	B2	B1	B2	B2
Surveillance	2	2	2	2	B2	B1	B2	B2
Emergency response	2	2	2	2	B2	B1	B2	B2
Diagnostic services	2	3	3	2	B2	B1	B2	B2
Research/ technology development	3	2	2	2	B2	B2	B2	B2
Information management	3	3	2	4	B2	B2	B2	B1
Advisory services	2	4	2	4	B2	B2	B2	B2
Input supply	3	4	3	3	B2	B2	B2	B2
Policy and regulation	1	2	1	2	B2	B2	B2	B2

Performance indicator scores (See Additional file Table B for associated indicators reflected by: 1 = no or very limited delivery of responsibilities; 2 = some delivery of responsibilities; 3 = average delivery of responsibilities; 4 = strong delivery of responsibilities; and 5 = very strong delivery of responsibilities). Contextual factor scores: B1 = minor barrier; B2 = major barrier; D1 = minor driver; and D2 = major driver.

In most cases, contextual factors (finance, staffing, governance and communication) were considered major barriers to the effective functioning of the invasive species system. For example, although several institutions have quarantine facilities e.g. KALRO, KEFRI KEPHIS and NMK, these are physically concentrated in Nairobi and not easily available for everyone to access; surveillance is inconsistent (although routine in the livestock sector); and emergency response occurs in isolation resulting in a lack of ability to control the spread of invasive species.

Participants concluded that Kenya does not have an emergency response system in place to effectively respond to an invasive species outbreak. Although a response happens, it is typically after delays and only when the problem becomes economically important and affects livelihoods. Participants felt that as a whole, Kenya is better at detection than prevention. There is a lack of coordination or clear strategy, which affects negotiations for resources and relevant capacity building, and has a detrimental impact on information sharing. However, there is generally a large pool of qualified technical staff to undertake functions of the system.

The overall system performance indicator scores given by participants for prevention, detection and control were rated on average at indicator level 2 (Table 7). A number of major barriers were identified for certain system functions, for example, participants stated that prevention and control were inhibited by finance, governance and communication barriers in achieving an effective invasive species system. Discussions supporting these scores are captured in Additional file Table G.

Table 7: Overall system performance scoring

	Performance indicator					
System functions	Availability, access, coverage	Acceptability	Timeliness	Affordability	Sustainability	Coherence
Prevention	2	3	2	2	2	2
Detection	3	3	3	3	3	2
Control	3	2	2	2	3	2
Overall system: 2						

	Contextual factors			
System functions	Finance	Staffing	Governance	Communication
Prevention	B2	B1	B2	B2
Detection	B1	B1	B2	B2
Control	B2	B1	B2	B2

Performance indicator scores (See Additional file Table B for associated indicators reflected by: 1 = no or very limited delivery of responsibilities; 2 = some delivery of responsibilities; 3 = average delivery of responsibilities; 4 = strong delivery of responsibilities; and 5 = very strong delivery of responsibilities).). Contextual factor scores: B1 = minor barrier; B2 = major barrier; D1 = minor driver; and D2 = major driver.

Participants recommended that an invasive species management strategy should be developed adopting a multi-species approach followed by the establishment of a permanent body that is responsible for regulating the system (i.e. the equivalent to the

national climate change council). This coordinating body should be a government agency to ensure policy which is backed up by law. It should be supported by an overarching inter-ministerial committee whose sole mandate is to tackle invasive species

Findings on the invasive species system in Zambia

The approach used in Zambia provides useful insights into the current functioning of the invasive species system. Key actors involved in the interview process included various departments under the Ministry of Agriculture and the Plant Quarantine and Plant Services (PQPS) as the NPPO under Zambia Agricultural Research Institute (ZARI) as well as a range of other NGOs and organisations (Table 8). In the context of invasive species Zambia was one of the focus countries of the United Nations Environment Programme (UNEP) / Global Environment Facility (GEF) funded 'Removing Barriers to Invasive Plant Management' (RBIPMA) project implemented between 2005 and 2011 under the Global Invasive Species Programme (GISP). This programme contributed to the formation of a NISSAP for Zambia and the inclusion of IAS consideration in the revised NBSAP (#1), in the Environmental Management Act No. 12 (of 2011) and in the Fifth National Development Plan (FNDP).

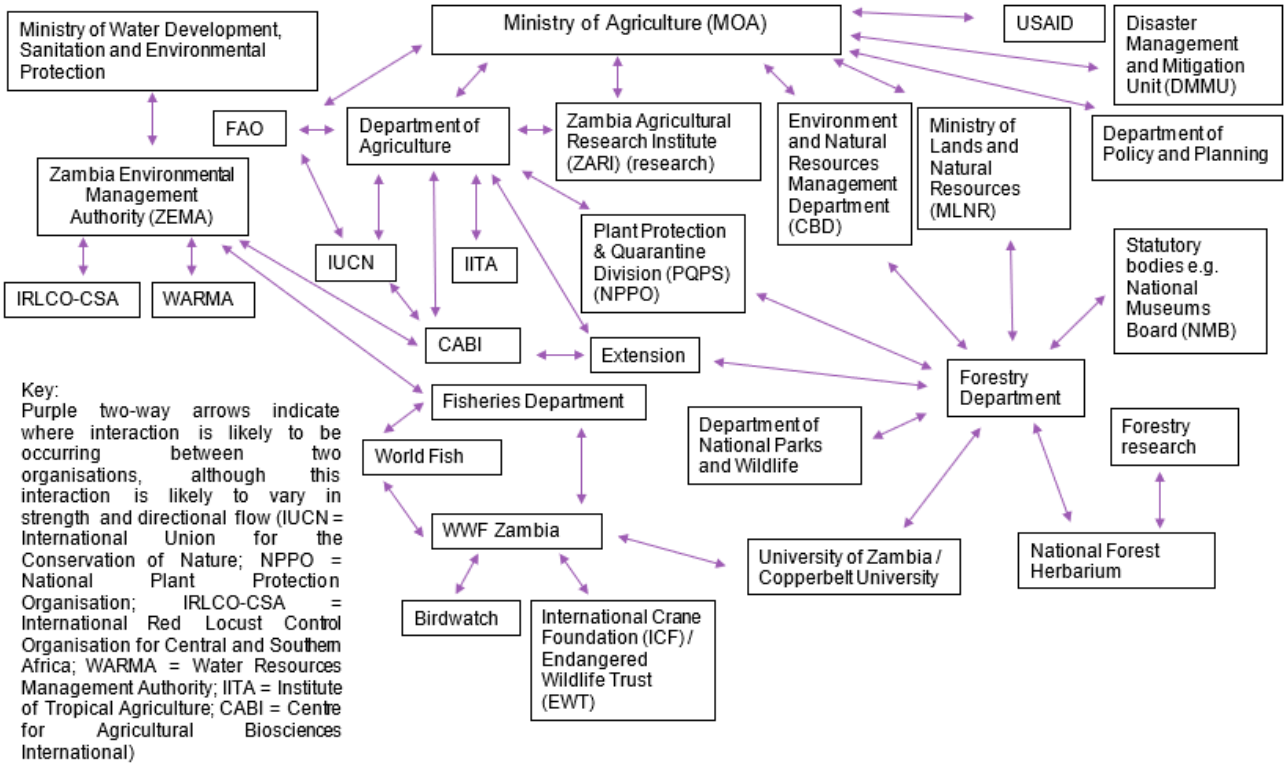
Table 8: Key organisations active in the invasive species system in Zambia

Zambia actors	
Ministry of Agriculture • Crops Production Department • Forestry Department • Fisheries Department Ministry of Lands and Natural Resources (MLNR) Zambia Environmental Management Agency (ZEMA) Disaster Management and Mitigation Unit (DMMU)	Research and regulation • Zambia Agricultural Research Institute (ZARI) - Plant Quarantine and Plant Services (PQPS) as the NPPO NGOs / International Organisations • BirdWatch Zambia (BWZ) • International Crane Foundation (ICF) • World Wildlife Fund (WWF) • Food and Agriculture Organisation (FAO) (Agronomist)

Upper Zambezi programme landscape manager Team Leader for the development of NBSAP #2 (FAO expert)	• USAID (Natural resource specialist)

The strengths identified in the Zambian system include the broad range of actors in the IAS space with technical expertise, commitment and modest funding to deliver on their mandates. Collaborative partnerships were also evident e.g. Birdwatch Zambia (BWZ) is currently working on the control of *S. molesta* in the Lukanga Swamps and has established a Steering Committee which constitutes most of the key actors working on IAS management, including ZEMA, and there is also an established national task force for Fall armyworm (FAW) (*Spodoptera frugiperda*). Another strength is the track record of past and present results for learning, e.g. BWZ's active control of *S. molesta* demonstrates successful utilisation of a biological control agent. Key actors consulted referred to active community participation in IAS management, particularly in the control and management stage. All the NGOs and most of the line ministries reported being actively involved in facilitating community participation in the sustainable management of IAS. Another strength of the current system is that there is a mandate for coordination of the IAS system and policy support under ZEMA who has responsibility for overseeing the coordination mechanism that was developed ten years ago. Figure 7 provides a preliminary key actor map based on the KII discussions for the invasive species system in Zambia. The arrows on the map indicate where interaction between actors is likely to be occurring. However, in the absence of the stakeholder workshop and discussion around these interactions it was not possible to accurately determine all of the interactions occurring or their frequency and the direction of information flow.

Figure 7: Key actors identified in the invasive species system in Zambia



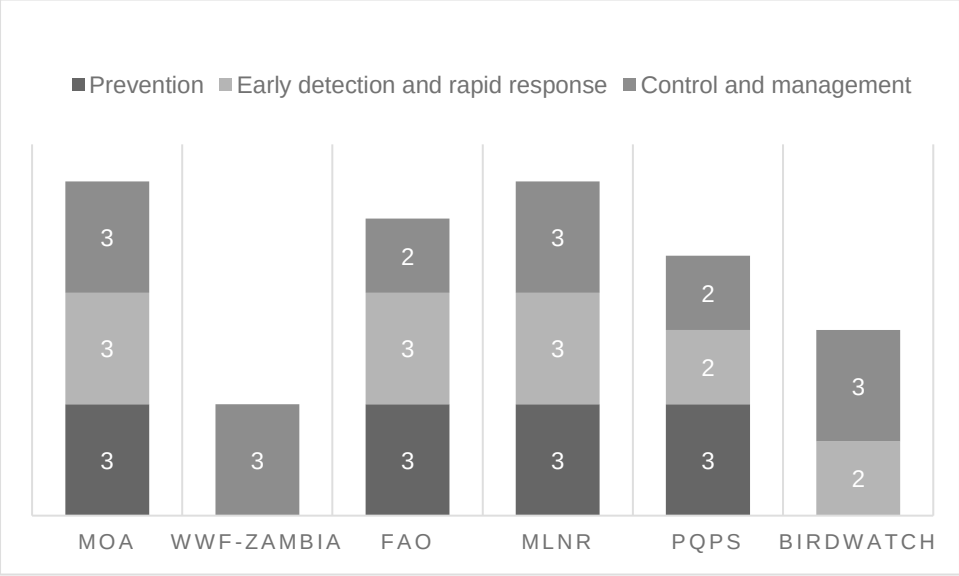
The challenges identified in the Zambian system include weak coordination. Despite the efforts to establish an effective coordination mechanism through an apex body and the fact that ZEMA is recognised as the responsible unit to oversee national coordination of the IAS agenda, the mechanism is not formalised. This has resulted in a tendency for a fragmented approach to implementation of IAS management activities which is found to be particularly sector based. The RBIPMA project made a major contribution to the formation of the NISSAP, but closure of the project and the absence of a coordination mechanism meant there was no follow up to the NISSAP. A related weakness, resulting from weak coordination, is the poor communication among the actors in the IAS system. Information sharing on IAS management is not effective with no national reporting mechanism or system for storage of information on IAS. Regular monitoring is essential for an effective early warning system and to help prevent the spread of IAS but currently there is isolated monitoring by actors in their areas of operation. There is also limited specific training on IAS and little provision of resources e.g. few diagnostic laboratories where organisations such as ZEMA can confirm identifications. Concern was also raised that in some instances high levels of staff turn-over results in a vast amount of knowledge being lost.

A final observation of the system in Zambia is that the operations of most of the actors in the invasive species space tends to be reactive rather than proactive. While this

was attributed to low levels of funding particularly for the government programmes, it was also observed that this was a factor of inadequate planning as well as the inadequate coordination and reporting of activities at the national level. As a result of this scenario, for most activities, there are no contingency plans for IAS even in cases where outbreaks are frequent. According to the DMMU, other emergency situations such as floods and droughts have contingency plans in place resulting in proactive action. This needs to be promoted in the case of IAS with a conscious move away from reactionary, often emergency, responses to threats, with the concept of preparedness adequately institutionalised.

Some informants ranked their organisation's performance in regards to the three areas of invasive species management: Prevention, Early detection and rapid response, and Control and management (Fig. 7). Although limited by subjectivity and not all actors provided self-assessment scores, this provides an indication of where organisations felt their current expertise lies. For example, Fig. 8 clearly shows that some organisations viewed their performance as high related to prevention (MOA, FAO, MLNR and PQPS), while scores for control and management indicated moderate to high performance, for example, MOA, WWF, MLNR and BWZ self-ranked as highly performing whereas FAO and PQPQ rated themselves as moderate, potentially also reflecting the organisations' mandated responsibilities.

Figure 8: Actor self-assessment of level of involvement in IAS activities



643 Actor self-assessment in the three steps of invasive species management: Prevention; Early detection
644 and rapid response; and Control and management (scores: 1 = poor; 2 = moderate; 3 = high [level of
645 involvement in IAS management stage]).
646
647 ## Discussion
648
649 A key part of this work was to develop an assessment method to determine the current
650 status of a country's invasive species system. The method was piloted in Kenya, and
651 the following discussion considers the first use of this method and some of the
652 feedback received from the participants engaged in the process. Although the
653 stakeholder workshop was not possible in the Zambia system assessment, valuable
654 insights into the current functioning of the invasive species system were still gained.
655 The value of the assessment method is highlighted as the results clearly show that
656 engaging various actors in a workshop environment significantly contributed to depth
657 of understanding as well as facilitating high levels of participant engagement and
658 discussion, and the opportunity to use quantitative evaluation tools such as indicators
659 to measure overall system performance.
660
661 *Evaluation of the assessment approach*
662 Desk review
663 The desk review was critical in providing sufficient background information to select
664 key actors in the system to invite to the workshop, and to identify key informants. In
665 Kenya, this step enabled the workshop, as the key stage in the assessment process,
666 to be carried out effectively.
667
668 Workshop
669 The Kenyan workshop participants responded positively to the approach presented
670 demonstrated by their active engagement in the activities and discussions throughout
671 the workshop. As the workshop progressed, participants continued to contribute, and
672 in some instances lead sessions and/or re-cap sessions. Participants were confident
673 to challenge opinions when necessary i.e. when an indicator was not clear or the
674 wording not entirely appropriate, or if a group allocated a score that differed from their

own opinion/experience. A key objective of the workshop was to ensure participants had ownership of the results and to develop concrete next steps. Participants reported that the various activities helped them to really think about the system. For example, when ministries were listed as an actor, participants only considered their policy and regulatory role e.g. connections between the Ministry of Environment and Ministry of Foreign Affairs on invasive species. However, it was necessary to unpack the departments under the ministries in order to understand the key players to talk to, with most ministry functions then considered as part of their subordinate department roles.

Participants reported that the actor interaction scoring activity helped them to identify unknown institutions and the roles they play, the absence of a national invasive species strategy, and the known and unknown links between key actors. It also helped them to see the need for interactions between the various actors and the value of improving interactions in order to manage invasive species effectively. The mapping exercise illustrated the complexity of the whole system, and how the actors interacted. It helped participants think about whether actors are communicating, how they interact, and whether their interactions achieve anything. The exercise highlighted that there is no central body/coordinator to bring all stakeholders' issues together and that Kenya does not have a strategy on invasive species as a whole (although many participants assumed the country had one) and how little coordination there is in the current system. However, in order to strengthen national legal and institutional frameworks, a coordinating mechanism and process between different departments and levels of government is needed (McNeely *et al*., 2001). Further, as demonstrated in the South African Working for Water Programme, an integrated cross-sector approach is pivotal to a programme's effectiveness (Boy & Witt, 2013).

Participants also made recommendations for improving some of the activities. For example, they commented that a single map of the whole system was unable to capture its complexities and instead recommended drawing a map per function to describe the linkages within each function, followed by one map of the system as a whole. This would provide a better understanding of how each function is able to deliver what is expected of it, and then how the system's actors interact overall.

Terminology was also questioned for example, it was not clear to participants what the phrase ‘driver of change’ meant in relation to contextual factors, after considerable discussion the term was changed to ‘enabler of change’ which was considered a clearer term. In addition, the indicators were redefined to be considerably more specific, with defined ratings, as recommended by the workshop participants. When the overarching system functions were considered, sustainability indicators were originally only developed for the overall system. However, participants considered that sustainability was also relevant when thinking about how the system is able to deliver the overarching prevention, detection and control functions. Indicators for these were subsequently developed and are included in the supplementary information, Table G.

Much of the richness of the process was in the discussions and the qualitative data captured. The combination of group work and plenary sessions enabled participants to challenge scores from other groups, and discuss whether the assessments were a fair judgement of the current system performance. This helped to ensure that participants owned the results, as did asking participants to lead the plenary discussions and recap sessions. Ownership of the results by the country participants was an essential part of the process, so that key actions and further development of an invasive species system could be taken forward.

Key informant interviews

In Kenya the KIIs helped triangulate the data from the workshop and were most useful in gathering further information on policies, regulations and specific roles and mandates when they were still unclear after the workshop. They were also critical where the actor was unable to join the workshop, and to identify other more minor actors to consider. Another benefit from the KIIs was that the additional discussions built further ownership and momentum to strengthen the invasive species system.

Evaluation of the current status of the invasive species system in Kenya and Zambia

This assessment provided an insight into the current functioning of the invasive species systems in Kenya and Zambia. A number of key challenges were identified

738 that apply across both countries. The lack of finance, governance and leadership were
739 identified as major barriers to effective system performance. Another key constraint in
740 both countries was the lack of a central coordinating body to guide invasive species
741 management. As signatories to the CBD, both countries have made a commitment to
742 increase cooperation between sectors involved in invasive species, including the
743 private sector, local communities and all levels of government, to create coordinating
744 mechanisms at the national level and work on a regional level to address invasive
745 species (CBD, 2002). The lack of a coordinating body, and the fact that invasive
746 species are not treated as a specific known entity to address, means that invasive
747 species are everyone's responsibility and therefore no one takes leadership or
748 ownership, and that budgets are not assigned for invasive species prevention and
749 management. Even when a NISSAP has been developed, as is the case for Zambia,
750 without the necessary coordination, it is not being implemented. In Kenya, a national
751 strategy is being developed for *Prosopis sp.*, as well as an IAS strategy for protected
752 areas (Arne Witt, *pers. comm.*) again highlighting the need for coordination at the
753 national level to produce and subsequently implement a NISSAP.
754
755 Although invasive species are hugely problematic in the study countries, any work to
756 address them is currently occurring mainly in isolation, although collaboration is
757 occurring in some instances. There are no structures, systems or clear authorities in
758 place to guide invasive species management, and lots of fragmented pockets of work
759 on invasive species are taking place through different institutions but with no overall
760 coordination. This finding is in line with that of other studies (Early *et al*., 2016; Perrings
761 *et al*., 2010) with few countries having the necessary institutions or regulatory
762 framework to manage invasive species. This finding also complements research from
763 other countries (DEFRA, 2014) which highlights that animal and plant health science
764 is too complex to self-organise, leading to the duplication of work and/or gaps in skills
765 and research, and a reduction of interdisciplinary capabilities. The lack of clear policy
766 or regulatory and legal frameworks for invasive species management compounds the
767 isolated working, as highlighted by Perrings *et al* (2010). Furthermore, there is no
768 common objective and no overarching or specific legislation on invasive species
769 management which leads to the system not performing effectively due to the
770 fragmented approach (McNeely *et al*., 2001; Shine, 2008; Young, 2006). Currently, it

771 is only when a new invasive species arrives and causes problems that people react,
772 especially when there are limited funds (Wittmann *et al*., 2015). Indeed, policies and
773 capacity to tackle invasive species are often found to be lacking in low Human
774 Development Index countries, including the whole of Africa (Early *et al*., 2016).
775
776 Participants in Kenya also reported a lack of awareness of different institutions'
777 mandates and a subsequent lack of collaboration with respect to invasive species
778 management. Many organisations have invasive species management in their
779 mandates and strategies e.g. KALRO, KEFRI, KEPHIS, KFS and NMK (due to crop
780 losses) but other actors are unaware of this, or the actions they are taking. This lack
781 of awareness of others' mandates and actions has led to a lack of collaboration,
782 coordination and interaction; the improvement of which should lead to improved policy
783 design and implementation (Ekboir & Rajalathi, 2012). This situation has been
784 compounded by a devolution of responsibilities (although that is improving with more
785 synergy between national and county levels) as roles and actions for responding to
786 different species vary between county and national governments. For instance, plant
787 and animal diseases are managed through the counties, whereas migratory and cross-
788 border species are the national government's responsibility.
789
790 Currently, Kenya has a single species approach to management, dealing with each
791 invasive species as it arises, but participants recognised that an overarching
792 framework to manage multiple invasive species would enable improvement in
793 management actions. Reactive national policies aimed at managing established
794 problematic invasive species are also more common than proactive policies in Africa
795 (Early *et al*, 2016). Participants recognised that there is limited forecasting and
796 detection of new pests, due to the lack of an early warning system, and because of
797 that, prevention of new pest incursions is difficult. Resource mobilisation was a related
798 challenge, especially in relation to new pest invasions, meaning that response
799 measures were often delayed due to a lack of funds. There are currently limited
800 approved intervention measures for newly reported pests, again reducing the
801 responsiveness of the system. Participants noted that the country needs to become
802 more pro-active to address invasive species.
803

The assessment process in Kenya not only enabled participants to assess and analyse the current state of the invasive species system, but also facilitated the process of developing the next steps and finding a way forward to improve the system and its component parts, based on their own assessment of its responsiveness to invasive species. Their key recommendation was that an invasive species management strategy should be developed followed by the establishment of a permanent body that is responsible for regulating the system and managing invasive species in a proactive manner. The established body would also be in a position to ensure the integration of invasive species management into larger government programmes. The situation in Zambia is similar although a management strategy in the form of a NISSAP has already been developed - the key question now is how to engage and formalise the establishment of the coordination mechanism under ZEMA. The coordinating body should have adequate representation from all sectors involved in invasive species management and the ability to effectively bring all stakeholders together to rapidly increase the profile of the invasive species issue. The coordinating body, it is hoped, would help to assist in addressing the serious resource issues that prevent current management and effective mitigation of new/invasive pest outbreaks at the detection and prevention stage, rather than relying on emergency response measures aimed at control once the pest has already become established.

This conclusion by the actors within both invasive species systems is in line with conclusions reached and actions taken by others in South Africa and the USA (Terblanche *et al*., 2016; Wilson *et al*., 2013; Wittmann *et al*., 2015). Participants noted that at policy level, environmental, social and economic aspects of sustainability must be incorporated into any proposed invasive species management strategy in order to support those working on the ground (Larson *et al*., 2011).

Conclusion

When commencing this research, we set out to understand the current status of the invasive species systems in Kenya and Zambia. In order to do that, we had to define the system and its component parts, as well as design an assessment method.

The value of this systems approach can be clearly seen in the study results especially when utilised fully as in the Kenya study. It is only by bringing together the various actors that we can truly understand how the system is or is not operating. The value of the stakeholder workshop is clearly evident with the Kenyan study results providing depth of information in qualitative terms as well as the ability to use indicators to measure the system performance in quantitative terms, with all the tools offering value and complimenting each other. Without the workshop in Zambia we still managed to gather in depth information but the process significantly lacked interaction between the key actors, which were an important and significant part of the process in Kenya, especially in determining the key next steps and a forward plan. In a different country context to Zambia, where previous invasive species work has not taken place, the assessment process without the stakeholder workshop would seriously lack the actor interaction and discussion and subsequently ownership and development of a clear plan and path forward in managing IAS.

The invasive species systems approach piloted in Kenya facilitated stakeholder engagement in clearly defining and understanding the system in Kenya as it currently stands. Defining functions and indicators helps partners to see what is critical, as well as potential collaboration opportunities to ensure effective system functioning, which will form a basis for future system assessment. Participants successfully completed a self-assessment of their own system strengths and weaknesses, and importantly planned a clear way forward based on this understanding and insight. The results can also form either a baseline assessment or a comparative assessment if repeated, to understand what changes have happened over time within the invasive species system. Further, the approach and tools demonstrated here have been developed so that they are applicable to other countries' invasive species system self-assessments, with adjustments to specific country contexts. The assessment in Zambia was intended to demonstrate the use of the approach in another country context. Although the process could not be fully employed it was possible, by engaging with key actors in the system in an interview context, to obtain insights and understanding of the current system functioning although the process lacked the participatory elements and opportunity for essential actor engagement.

This study provides a framework for a country-level assessment of responsiveness to invasive species. The insights gained will contribute towards the use of various toolkits designed to help countries effectively manage IAS and support key actors in the next steps towards embedding IAS as significant national priorities. However, as Perrings *et al* (2010) highlight, there is an urgent need for global cooperation and coordination, and an international mechanism for invasive species prevention, detection and control, also outlined by Wittenberg & Cock (2001). The proposed framework for a national assessment provides key information that would contribute to such international efforts whilst also offering an opportunity for countries to learn from each other to improve areas of weakness. This would ultimately help shift the balance towards the prevention of, instead of reaction to, new invasive species incursions in the first instance.

List of abbreviations

AFA	Agricultural and Food Authority
AIS	Agricultural innovation system
BWZ	BirdWatch Zambia
CBD	Convention on Biological Diversity
CBO	Community based organisation
DMMU	Disaster Management and Mitigation Unit
EWT	Endangered Wildlife Trust
FAO	Food and Agriculture Organisation
FAW	Fall armyworm
FNDP	Fifth National Development Plan
GEF	Global Environment Facility
GISP	Global Invasive Species Programme
ICF	International Crane Foundation
IICA	Inter-American Institute for Cooperation on Agriculture
IITA	International Institute of Tropical Agriculture
IPPC	International Plant Protection Convention
IRLCO-CSA	International Red Locust Control Organisation for Central and Southern Africa
ISPMs	International Standards for Phytosanitary Measures
IUCN	International Union for the Conservation of Nature

JASCOM	Joint Agriculture Sector Consultation and Cooperation Mechanism
KALRO	Kenya Agriculture and Livestock Research Organisation
KEFRI	Kenya Forestry Research Institution
KENAFF	Kenya's National Farmers' Federation
KEPHIS	Kenyan Plant Health Inspectorate Service
KFS	Kenya Forestry Service
KII	Key informant interview
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KWS	Kenya Wildlife Service
MLNR	Ministry of Lands and Natural Resources
MOA	Ministry of Agriculture
MoALF	Ministry of Agriculture, Livestock, Fisheries and Cooperatives
NACOSTI	National Commission for Science, Technology & Innovation
NBSAP	National Biodiversity Strategy and Action Plan
NEMA	National Environment Management Authority
NGO	Non-governmental organisation
NISSAP	National Invasive Species Strategy and Action Plan
NMB	National Museums Board
NMK	National Museums of Kenya
NPPO	National Plant Protection Organisations
PCE	Phytosanitary Capacity Evaluation
PCPB	Pest Control Product Board
PQPS	Plant Quarantine and Plant Services
PVS	Performance, Vision and Strategy
RBIPMA	Removing Barriers to Invasive Plant Management
SPS	Sanitary and phytosanitary
UNEP	United Nations Environment Programme
WARMA	Water Resources Management Authority
WWF	World Wildlife Fund
ZARI	Zambia Agricultural Research Institute
ZEMA	Zambia Environmental Management Agency

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article and its supplementary information files.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

FW, RD, IR, KC and JG all contributed to critical early stage thinking and conceptualisation of the theoretical framework and methodology as outlined in the manuscript. FW and KC developed the participatory tools and indicators used in the workshop. AA, EL, GM, SK and TK all participated in the Kenyan stakeholder workshop, contributing to refining the assessment process and were central to the interpretation of key findings as presented in the manuscript. FW led the Kenyan workshop with facilitation support from IR and KC. FW, JMM and KC conducted the

study in Zambia contributing to interpretation of the findings as presented in the manuscript.

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Availability of data and material

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