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An assessment of the capacity and responsiveness of a national system to address the threat of invasive species: a systems approach

F. Williams[1], K. L. Constantine[2*], A. A. Ali[4], T. W. Karanja[5], S. Kibet[6], E. K. Lingeera[7], G. Muthike[8], I. Rwomushana[1], J. Godwin[3] and R. Day[1]

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. 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.

Results: Actors who are active in managing invasive species were identified and engaged. The assessment process provided insights into the current functioning of the invasive species system. A number of key challenges were identified, for instance, the lack of finance, governance and leadership, 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.

Keywords: Systems approach, Invasive species system, Self-assessment, Responsiveness, Kenya

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. Many

*Correspondence: k.constantine@cabi.org
[2] CABI, Egham, UK
Full list of author information is available at the end of the article

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international conventions recognise the threat from invasive species. 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). The revised Strategic Plan for Biodiversity, adopted at the CBD conference of parties in 2010, included the Aichi Biodiversity Targets. Target 9 states that 'By 2020, invasive alien species and pathways are identified and prioritised, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment' (CBD 2010). Signatories have a responsibility to manage invasive species through their eradication, and management of introduction pathways: therefore countries need the necessary capacity and effective control structures in place.

Invasive species affect many sectors within a country including agriculture, environment, human health, trade and water. Effective management requires concerted efforts from all actors involved, whose functions and roles are complementary; no single organisation can manage invasive species in isolation. 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 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.

Biosecurity systems have many similarities with invasive species systems, where biosecurity is defined as 'a strategic and integrated approach to analysing and managing relevant risk to human, animal and plant life and health and associated risks for the environment' (INFOSAN 2010). Both systems consider control of imports, domestic movement and exports of animals and plants, including invasive species (FAO 2007), with an emphasis on prevention. Biosecurity systems also address topics including endemic diseases, emerging zoonoses, food safety and antibiotic resistance (FAO 2007). There is a strong focus on risk assessment and management (Dahlstrom et al. 2011), especially in relation to border threats, surveillance, and pathway analysis (Rainford et al. 2020). Hulme et al. (2020) examine biosecurity systems in the context of the dynamics of biological invasions and stopping the spread of invasive species. Biosecurity systems can also be sector specific in their approach to managing risk (Quinlan et al. 2021) and van Klinken et al. (2020), where a phytosanitary systems approach is used. However, invasive species systems are both broader and narrower than risk focused biosecurity systems, in that they include management of established invasive species (beyond managing invasion risk), but only focus on invasives species, not other risks such as endemic diseases or antibiotic resistance. When considering the concept of 'One Biosecurity' proposed by Hulme (2020) an invasive species system is considered as a component of, and nested within, this wider biosecurity system contributing towards a systematic, integrated approach transcending traditional boundaries and sectoral identities (Hulme 2020, 2021).

Biosecurity and its goals are well defined (INFOSAN 2010). Definitions of other systems also provide a basis for defining an invasive species system within a biosecurity system. 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. Within SPS systems, Day (2013) lists the component parts as: actors, functions, linkages, measures, policy and governance, and SPS standards and compliance. Danielsen and 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. Latham (2014) defines these linkages as the "organisational and inter-organisational arrangements" that enable a system to deliver its aims and outcomes including laws, policies and regulations. FAO and CIRAD (2018) note that systems include the relationships and knowledge flow between actors, and that systems evolve as the component parts change.

Attempts have been made to evaluate other systems such as biosecurity, SPS, Agricultural Innovation

Systems (AIS) and plant and human health systems. FAO, through their Biosecurity Toolkit (2007) provide a guide on assessing biosecurity capacity. 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 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 (IUCN 2000, 2018; Wittenberg and Cock 2001) as well as those for biosecurity (FAO 2007).

Methods

A methodology for evaluating the capacity and performance of a country in responding to invasive species was developed. First, an invasive species system and its component parts were defined. Second, a method was developed to understand the structure of a system (organisations and their mandates, policy, regulation etc.), and indicators to measure the system's current perceived performance. The method was 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. We discuss the value of the proposed approach to assessing the current status and functioning of an invasive species system.

Framing the invasive species system

We explored systems approaches and how these systems had been defined, structured, regulated and what elements were assessed when considering system performance. 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 and, accordingly, no defined assessment system. We therefore define an invasive species system as:

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. These are described in the following sections.

Components of an invasive species system

Based on the components described in the literature for other systems (Danielsen and Matsiko 2016; IUCN 2000, 2018; Williams et al. 2015; Wittenberg and Cock 2001), we identified a number of key components and functions

important in an invasive species system. Some functions are relevant to 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). System delivery is dependent on contextual factors including staffing, governance and leadership, finance and communications.

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 are needed to assess system performance. We therefore developed a three stage process: (1) Document/literature review, including development of overarching system definitions and indicators; (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 and Constantine (2019) provides a comprehensive account of the method and approach.

Step 1: Document review The literature review provided a general understanding of the invasive species system and its functioning within Kenya. We identified the key actors in invasive species management delivery, through a review of 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. Information that related to contextual influences, such as institutional structures, donor influences, politics and organisational culture, international, regional, central/local strategies, implementation plans and budgets, and key statistics were reviewed to provide sufficient information to be able to establish which actors were involved in each function.

Five function-level indicators were defined and one system-level indicator (Table 2) to enable assessment of how functions deliver their outputs, and how the system as a whole performs against its outcomes, 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) to assess whether they enabled functions to deliver outputs, or were a barrier to function and system delivery (see Additional file 1: Table S1 and Additional file 2: Table S2 for all indicators).

Official policy and institutional arrangements do not always reflect reality on the ground. Therefore, the document review only provided an entry point to understanding the system. The workshop was essential to gaining an in-depth understanding of the invasive species system in Kenya.

Step 2: Stakeholder workshop Based on the document review, twenty-four actors were invited to the workshop, ensuring both central and local-level representatives, and representatives from different levels of seniority, to ensure those present understood both policy and practitioner levels. The workshop, in Nakuru, Kenya, ran for 2.5 days, with a series of group and plenary sessions (Table 3). The final session focused on forward planning to address the key challenges identified. A detailed workshop guide is given in Williams and Constantine (2019).

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, the discussions around the scoring were captured to ensure the quantitative data could be explained through the qualitative information.

Step 3: Key informant interviews (KIIs) The KIIs were used to gap fill where actors were under-represented in the workshop, and to understand unclear or contradictory information from the workshop. They captured additional information about contextual influences such as the policy environment, institutional structures, donor influence, politics and organisational culture. They were also used to verify and triangulate the information collected from the workshop and literature. Four KIIs were conducted with: Agricultural and Food Authority (AFA), Kenya Wildlife Service (KWS), Ministry of Environment and Forestry, and the Joint Agriculture Sector Consultation and Cooperation Mechanism (JASCOM). Facilitators from the workshop carried out the KIIs to ensure that the knowledge from the workshop was used to tailor the interviews.

Results

The aim of the work was twofold: to assess the current state of the Kenyan invasive species system, and to test the assessment approach and tools used. The approach is discussed to establish whether this was a suitable method

Table 1 System functions, outcomes and contribution to outputs

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 Research knowledge and facilities	Development of relevant management practices and technologies for invasive species when required, that are feasible and affordable for farmers and other land users to implement	Cross cutting
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, biological control 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

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?

Table 3 Key steps and activities in the stakeholder workshop

Key steps	Detail on activity
Invasive species system functions	Discussion on function definitions (Table 1): whether the functions were correctly structured, whether the definitions were correct?
Actors in the invasive species system	Discussion on actor list (Table 4): were any actors missing; did the actor groups need breaking down into smaller groupings or combining to form a larger overall actor?
Actors within each invasive species system function	Discussion on actors within each function (Table 5): were the actors listed per function correct; did any actors need to be added or removed?
Actor scoring within functions[a]	Discussion and scoring of actors by function against predetermined indicators (scale of one to five) (Additional file 1: Table S1). 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 assessment of the system in its entirety)	Discussion on how actors worked and interacted together, and whether the relationship was one way (i.e. top down) or truly interactive. The exercise provided an overall picture of the complexities that are often intrinsic in such systems
Interaction scoring[b] (complementary to the mapping, a quantitative assessment of actor interactions)	Discussion and scoring of 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 focused on information and knowledge exchange, the level of coordination and feedback, and whether any financial mechanisms were involved
Invasive species system indicator performance scoring[c]	Assessment and rating of how each function as a whole performed against the defined performance indicators (Additional file 2: Table S2), as well as system-level performance indicators and the contextual factors
Planning a way forward	Review of findings, key issues, and current actions. Development of concrete plans for way forward

[a,b,c] Additional file 1: Table S1 and Additional file 2: Table S2 provide specific indicators however, in general the indicator scores for [a] and [c] 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 [b] are 0 = no interaction (but there should be interaction); 1 = weak interaction; 2 = average interaction; 3 = strong interaction; and 4 = very strong interaction

to evaluate the current status of an invasive species system in a country.

Invasive species system functions

Discussions on the 10 pre-defined functions (Table 1) confirmed that these functions were accurate and appropriate. However, participants highlighted that invasive species system co-ordination should be included as a function, as co-ordination has a central role and provides a focal point in the management/mitigation response to an invasive species threat. In addition, participants thought the functions were largely reactive rather than proactive in tackling invasive species.

Actors in the invasive species system

The participants agreed on the principal actors identified before the workshop, as well as additional actors (Table 4). These 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. The land users/managers actor group was clarified to include KWS and Kenya Forest Service (e.g. actors who manage land for conservation rather than food production); legislators and policy makers included the Council of Governors/County Governments/Kenya Institute for Public Policy Research and Analysis (KIPPRA); and the Crop Development Board, now AFA (who govern all the crop boards e.g. tea, coffee, sugarcane etc.) was included under research.

The lack of a coordination body for invasive species management was emphasised, and the need for clarification of each institution's mandates in order to fully understand their focus and responsibilities. Other actors that have a role in an invasive species system were identified, but participants recognised that these actors were not critical 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 stated 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, the International Centre of Insect Physiology and Ecology (*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. Unless the actors are working on a collaborative project it is very hard to know who to talk to, and no single institution has the responsibility of declaring an 'invasion' as an emergency. Moreover, emergency response needs coordination which is currently missing.

A number of 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. Information and Communication Technology (ICT) and the media were considered good avenues to reach farmers with information on invasive species. For example, the local media houses have independent television for farmers e.g. Kenya Television Network (KTN) Farmers, while others have dedicated programmes or newspaper pull-out editions e.g. Seed of Gold, from the Daily Nation.

Table 4 Actors within an invasive species system

Policy • **Legislators, policy makers** • **Ministry of Agriculture** • **Ministry of Environment** • Ministry of Trade • *Ministry of Foreign Affairs* • *Ministry of Education* • *Ministry of Finance, Revenue Authority*	Farming business • Farmers • **Farmer organisations** • Community-based organisations • Agro-dealers (village shops) • **Agro-input suppliers/import companies (suppliers of village shops, importers of pesticides etc.)** • **Extension department**	Land/aquatic management • **Forestry department** • Fisheries department • **Environmental protection agency** • **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 organisations—e.g. CABI, FAO, *icipe* and IPPC** • **Diagnostic laboratories** • **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 • Others e.g. **Precision Agriculture for Development (PAD)**	Media • TV • Radio • Print media • Journalists	*Development organisations* • *World Bank* • *Africa Development Bank etc.*

Actors in italics were not part of the assessment process; actors in bold attended the workshop or were interviewed separately; other actors were considered within the assessment process

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 (e.g. PAD)			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 function linkages marked in bold indicate where the actor has greater involvement in the function; actors in bold attended the workshop or were interviewed separately; other actors were considered within the assessment process

Actor scoring within functions

Most actors were currently performing at approximately the indicator three level, as these actors have some awareness of the need to manage invasive species (Additional file 3: Table S3: individual actor function scores, Additional file 4: Table S4: participant discussions on 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. 1).

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. 2). There was 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 for improvement, and an opportunity for system strengthening.

Actor mapping within system

The participants agreed the system was very complex (Fig. 3) and that the Ministry of Agriculture, Livestock, Fisheries and Cooperatives (MoALF) and Ministry of Environment are the two key organisations in the system, although the links between them are considered weak. Farmers, who have direct links with MoALF (via Kenya's National Farmers' Federation (KENAFF)), and biodiversity managers are also central to the system. For some actors i.e. JASCOM, there was insufficient knowledge about the organisation to comment on their linkages.

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, through its role in budget allocations. Budget policy makers need to be 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

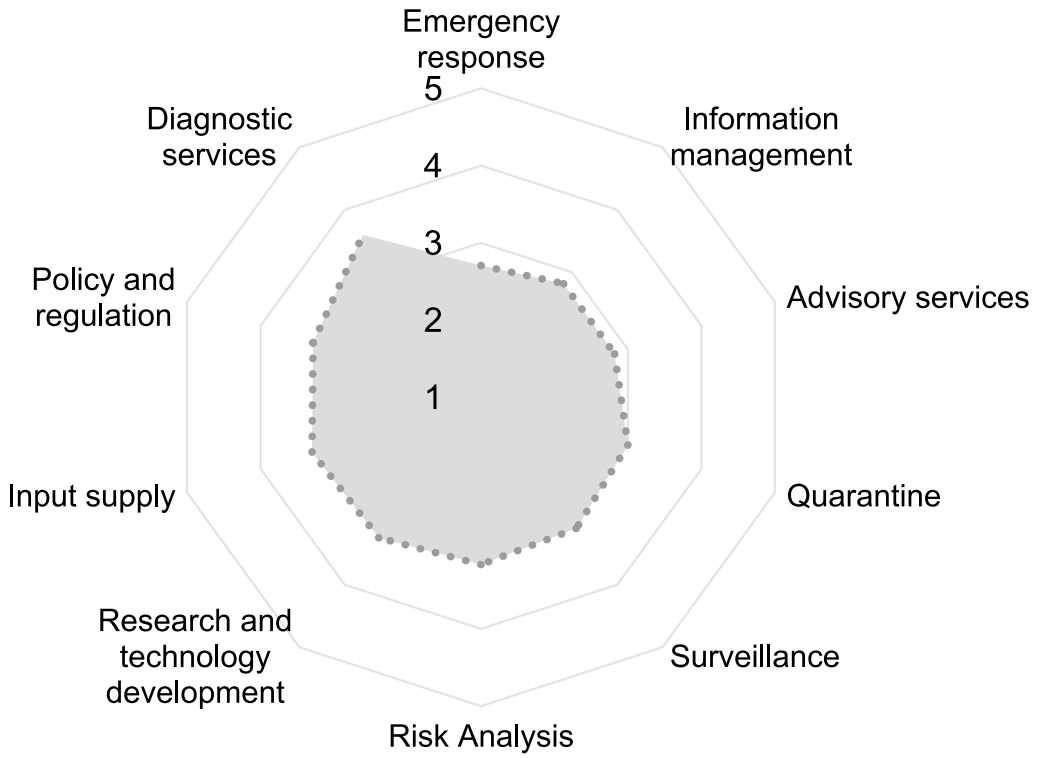

Fig. 1 Average actor score for each function. Average actor scores for the ten system functions. Indicator scores: 1 = no or very limited delivery of responsibilities; 2 = some delivery of responsibilities; 3 = average delivery of responsibilities; 4 = strong delivery of responsibilities; and 5 = very strong delivery of responsibilities

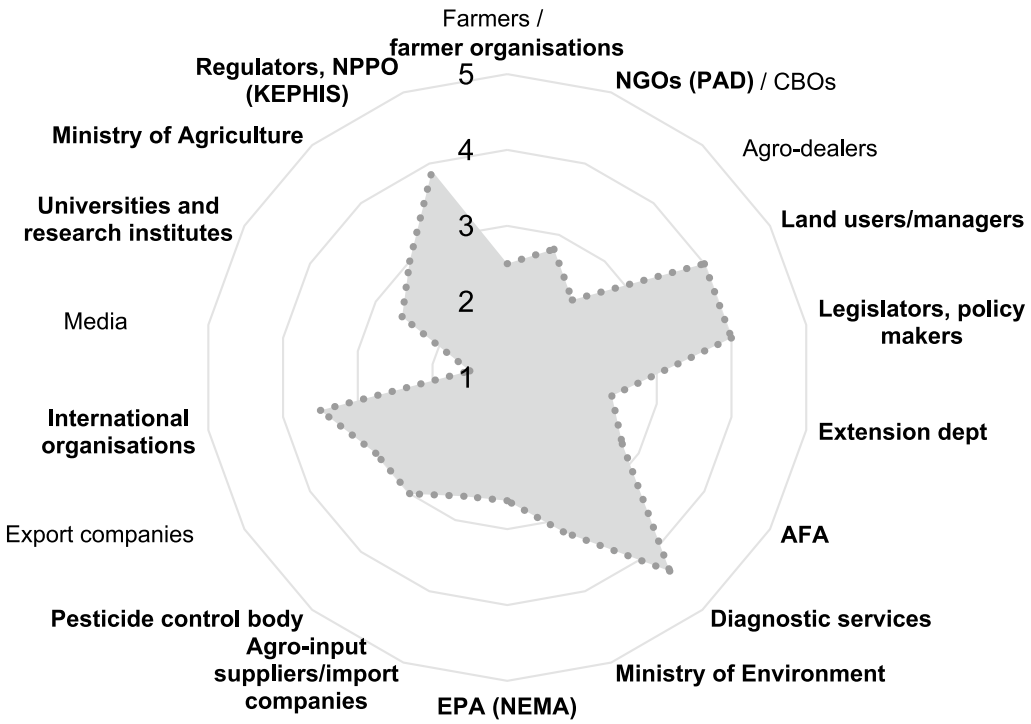

Fig. 2 Average actor scores across all functions. Average actor scores across the ten system functions. Indicator scores: 1 = no or very limited delivery of responsibilities; 2 = some delivery of responsibilities; 3 = average delivery of responsibilities; 4 = strong delivery of responsibilities; and 5 = very strong delivery of responsibilities; actors in bold attended the workshop or were interviewed separately; other actors were considered within the assessment process

of funds would be carried out by the other relevant ministries e.g. MoALF and Ministry of Environment.

Actor interaction scoring

The level of interaction between actors was classified, with a number of instances where there were either no interactions (where there should be one) or there was a weak interaction between actors on invasive species issues (Additional file 5: Table S5 and Additional file 6). For example, traders and transporters received a score of zero for eight interactions with other actors. Many interactions were considered average i.e. the actors are interacting but there is quite a lot of room for improvement (Fig. 4).

Some interactions were considered strong, such as those between farmers/farmer organisations and land users/managers, agro-input suppliers and export companies, or very strong e.g. with legislators/policy makers, the Ministry of Agriculture and international organisations. Participants noted that in general, there has been little interaction between actors on invasive species in the country, with any existing interaction related to general issues.

Invasive species system indicator performance scoring

The overall system performance assessment indicates 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 at a higher 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 are operating at a lower level e.g. for policy and regulation an indicator score of one was reported for both availability and timeliness. Overall, participants considered that the invasive species system is operating, but much needs to be improved before it could be considered to be optimal.

Contextual factors (finance, staffing, governance, communication) were considered major barriers to the effective functioning of the invasive species system (Table 6). 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

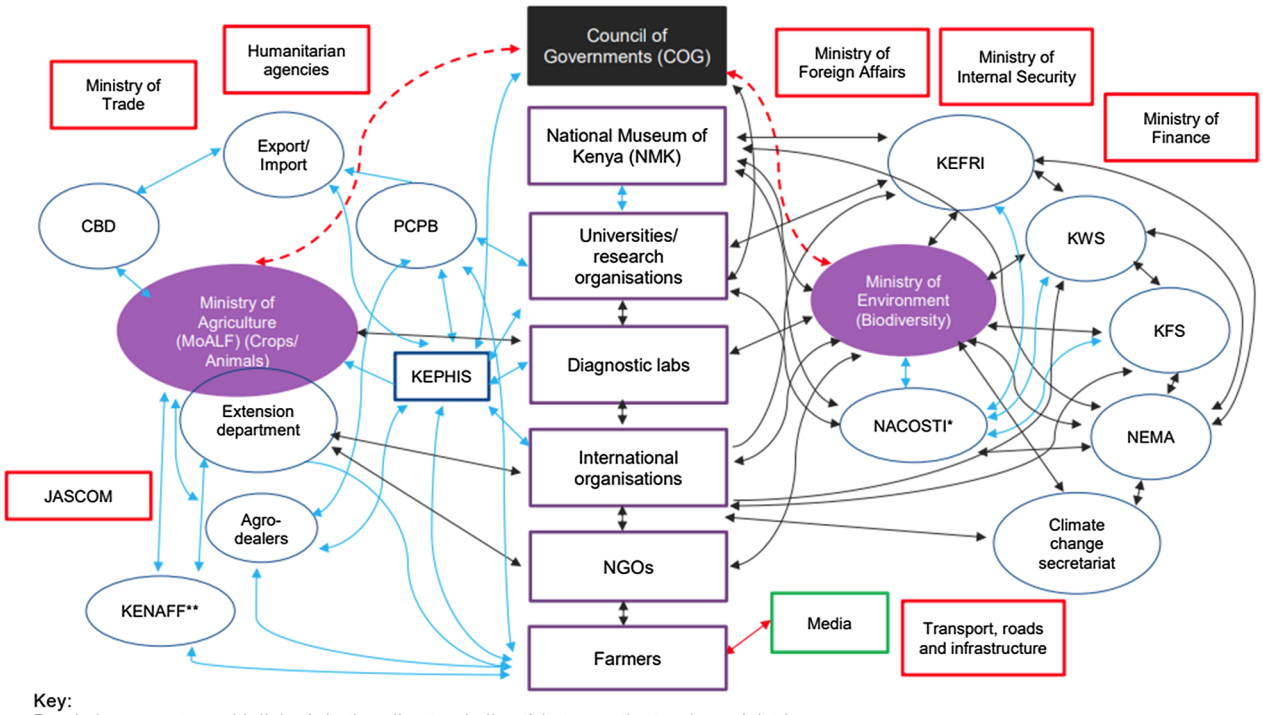

Fig. 3 Actor mapping. Workshop participants' map of actors and linkages in the current invasive species system in Kenya

sector); and emergency response occurs in isolation, resulting in a lack of ability to control the spread of invasive species.

There is an informal, multi-institutional technical committee who collaborate on invasive species. When aware of a new pest risk, the committee develop a policy brief and new technical materials to facilitate intervention. Briefs include information on expected economic impacts, and are presented to senior officials in the MoALF, in order to lobby for funding. For example, the committee successfully lobbied for government funds for fall armyworm (*Spodoptera frugiperda*) management which facilitated surveys on the extent of spread, development of training materials, training at county level, and development and harmonization of extension/awareness materials, as well as lobbying for funds from other sources through project proposals. However, the committee has no formal mandate, but rather work in an ad hoc manner depending on the good will of members. There is also narrow representation, as they are not able to bring on board all relevant institutions, due to lack of funds.

Participants concluded that Kenya does not have an emergency response system in place to respond effectively to an invasive species outbreak, and that Kenya is better at detection than prevention. Although a response happens, it is typically after delays and only when the problem becomes economically important and affects livelihoods. 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 a large pool of qualified technical staff to undertake functions of the system.

The overall system performance indicator scores for prevention, detection and control were rated on average at indicator two level (Table 7). A number of major barriers were identified for certain system functions, such as, prevention and control were inhibited by finance, governance and communication barriers in achieving an effective invasive species system (Additional file 7: Table S6).

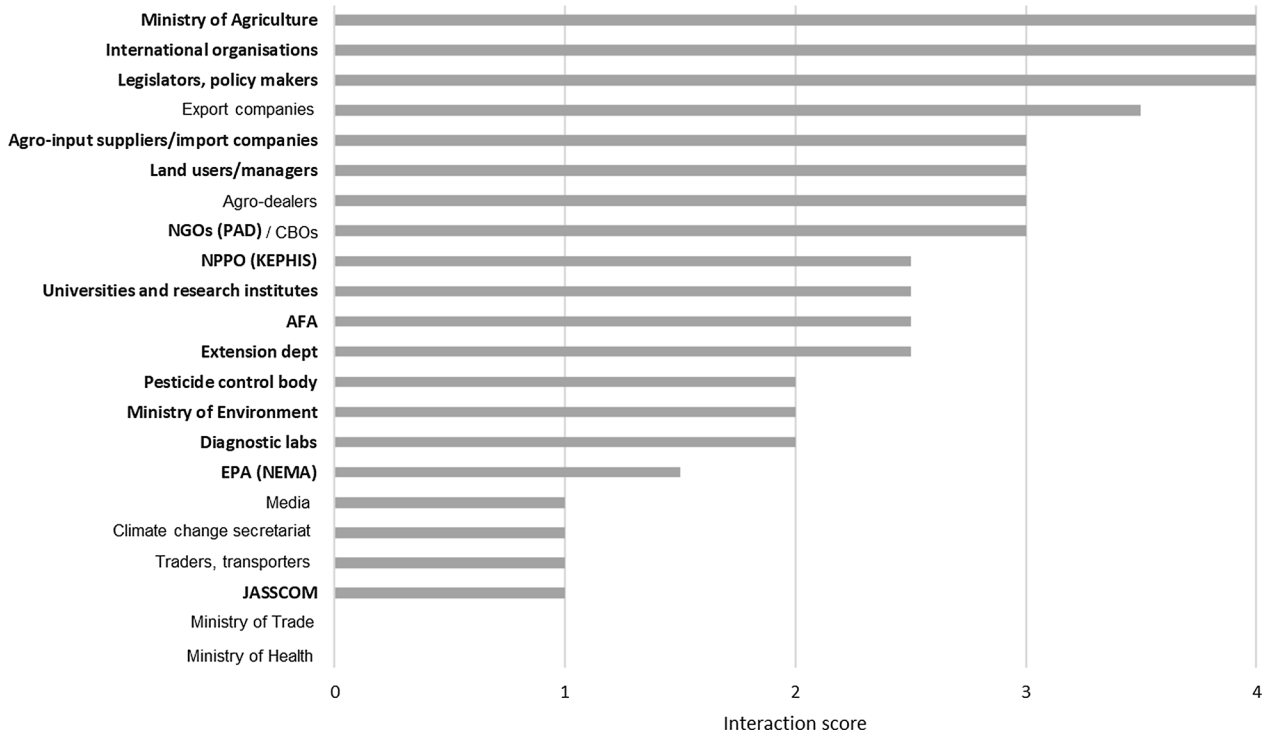

Fig. 4 Example of average scores participants allocated to farmer/farmer organisations' interactions with other actors. Interaction scores: 0 = no interaction (but there should be interaction); 1 = weak interaction; 2 = average interaction; 3 = strong interaction; and 4 = very strong interaction; actors in bold attended the workshop or were interviewed separately; other actors were considered within the assessment process

Table 6 System performance scoring

System functions	Performance indicator				Contextual factors			
	Availability, access, coverage	Acceptability	Timeliness	Affordability	Finance	Staffing	Governance	Communication
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

System performance indicator and contextual factor scores (see Additional file 2: Table S2 for system performance 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

Table 7 Overall system performance scoring

System functions	Performance indicator					
	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

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

Overall system performance scoring. Performance indicator scores (see Additional file 2: Table S2 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

The key recommendations were 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). The coordinating body should be a government agency to ensure policy backed by law. It should be supported by an overarching inter-ministerial committee whose sole mandate is to tackle invasive species.

Discussion

A key part of this work was to develop an assessment method to determine the current status of a country's invasive species system. The method was piloted in Kenya, and the following discussion considers the first use of this method, and some of the feedback received from the participants engaged in the process. The value of the assessment method is highlighted, as the results clearly show that engaging various actors in a workshop environment significantly contributed to depth of understanding, as well as facilitating high levels of participant engagement and discussion, and the opportunity to use quantitative evaluation tools to measure overall system performance.

Evaluation of the assessment approach

Document review

The document review was critical in providing sufficient background information to select key actors in the system to invite to the workshop, and to identify key informants.

Workshop

A key objective of the workshop was to ensure participants had ownership of the results, through active engagement and leading sessions. Participants challenged opinions when necessary i.e. when an indicator was not clear or the wording not entirely appropriate, or if a group allocated a score that differed from their own opinion/experience. 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. 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 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 to identify the need for interactions between 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. 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 and Witt 2013).

Participants also made recommendations for improvement. 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. The use of a 5-point scale for indicators could also be problematic and result in responses clustered around the mid-point (e.g. Figure 1) (Garland 1991). When the overarching system functions were considered, sustainability indicators were originally only developed for the overall system. However, sustainability was also considered relevant when thinking about how the system is able to deliver the overarching prevention, detection and control functions. Indicators for these were subsequently developed (Additional file 7: Table S6).

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.

Key informant interviews

The KIIs helped triangulate the data from the workshop and to gather further information on policies, regulations and specific roles and mandates that 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

This assessment provided insight into the current functioning of the invasive species systems in Kenya. Key challenges were identified including lack of finance, governance and leadership, which are major barriers to effective system performance. Another key constraint was the lack of a central coordinating body to guide invasive species management, with current work generally occurring in isolation through different institutions. As a signatory to the CBD, Kenya has a commitment to increase cooperation between sectors involved in invasive species, including the private sector, local communities and all levels of government, to create coordinating mechanisms at the national level, and work on a regional level to address invasive species (CBD 2011). However, there are no structures, systems or clear authorities in place to guide invasive species management. This finding is in line with that of other studies (Early et al. 2016; Perrings et al. 2010) with few countries having the necessary institutions or regulatory framework to manage invasive species. It is also supported by research from other countries (DEFRA 2014) which highlights that animal and plant health science is too complex to self-organise, leading to the duplication of work and/or gaps in skills and research, and a reduction of interdisciplinary capabilities. The lack of a coordinating body, and the fact that invasive species are not treated as a specific known entity to address, means that invasive species are everyone's responsibility and therefore no one takes leadership or ownership, and that budgets are not assigned for invasive species prevention and management. The lack of clear policy or regulatory and legal frameworks for invasive species management compounds the isolated working (Perrings et al. 2010). Furthermore, there is no common objective and no overarching or specific legislation on invasive species management which leads to the system not performing effectively due to the fragmented approach (McNeely et al. 2001; Shine 2008; Young 2006). Currently, it is only when a new invasive species arrives and causes problems that people react, especially when there are limited funds (Wittmann et al. 2015). Indeed, policies and capacity to tackle invasive species are often found to be lacking in low Human Development Index countries, including the whole of Africa (Early et al. 2016).

There was also a lack of awareness of different institutions' mandates and a subsequent lack of collaboration with respect to invasive species management. Many organisations have invasive species management in their mandates and strategies e.g. KALRO, KEFRI, KEPHIS, KFS and NMK but other actors are unaware of this, or the actions they are taking. This lack of awareness of others' mandates and actions has led to a lack of

collaboration, coordination and interaction; the improvement of which should lead to improved policy design and implementation (Ekboir and Rajalathi 2012). This situation has been compounded by a devolution of responsibilities (although that is improving with more synergy between national and county levels) as roles and actions for responding to different species vary between county and national governments. For instance, plant and animal diseases are managed through the counties, whereas migratory and cross-border species are the national government's responsibility.

Currently, Kenya has a single species approach to management, dealing with each invasive species as it arises. For example, a national strategy is being developed for *Prosopis* sp., as well as an IAS strategy for protected areas (Arne Witt, *pers. comm.*). In Kajiado county, universities formed a technical working group on *Ipomoea* (Convolvulaceae), tasked with presenting solutions to the county government. Within the Kenyan system, interactions and communication between actors associated with agriculture were also stronger than those related to biodiversity. An overarching framework, such as a NISSAP is needed to manage multiple invasive species through coordination at the national level. Reactive national policies aimed at managing established problematic invasive species are also more common than proactive policies in Africa (Early et al. 2016). There is limited forecasting and detection of new pests, due to the lack of an early warning system, and because of that, prevention of new pest incursions is difficult. Resource mobilisation was a related challenge, especially in relation to new pest invasions, meaning that response measures were often delayed due to a lack of funds. There are currently limited approved intervention measures for newly reported pests, again reducing the responsiveness of the system. A clear conclusion is that Kenya needs to become more proactive to address invasive species.

The key recommendation from this assessment is that a NISSAP 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 should ensure the integration of invasive species management into larger government programmes. The coordinating body should have adequate representation from all sectors involved in invasive species management and the ability to bring all stakeholders together to increase the profile of the invasive species issue. The coordinating body should 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. The key actors in the invasive species system in Kenya are aware of the extent, and threat, posed by invasive species and want to mitigate and manage them. However, support is needed to bring invasive species to the forefront and ensure coordinated, effective action.

This conclusion, by the actors within the invasive species system, 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

The invasive species system approach and methodology piloted in Kenya are applicable to other countries' invasive species system self-assessments, with adjustments to specific country contexts. The insights gained will contribute towards managing IAS and embedding invasive species management as a significant national priority. The proposed framework provides key information that should contribute towards international efforts to manage invasive species, as there is an urgent need for global cooperation and coordination (Perrings et al. 2010), and an international mechanism for invasive species prevention, detection and control (Wittenberg and Cock 2001). This would ultimately help shift the balance towards the prevention of, instead of reaction to, new invasive species incursions in the first instance.

Abbreviations

AFA: Agricultural and Food Authority; AIS: Agricultural innovation system; CABI: Centre for Agricultural Biosciences International; CBD: Convention on Biological Diversity; CBO: Community based organisation; FAO: Food and Agriculture Organisation; IAS: Invasive Alien Species; *icipe*: International Centre of Insect Physiology and Ecology; ICT: Information and Communication Technology; IICA: Inter-American Institute for Cooperation on Agriculture; IPPC: International Plant Protection Convention; 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; KTN: Kenya Television Network; KWS: Kenya Wildlife Service; 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; NMK: National Museums of Kenya; NPPO: National Plant Protection Organisations; PAD: Precision Agriculture for Development; PCE: Phytosanitary Capacity Evaluation; PCPB: Pest Control Product Board; PVS: Performance, Vision and Strategy; SPS: Sanitary and phytosanitary; UNEP: United Nations Environment Programme.

Supplementary Information

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Additional file 1: Table S1. Actor Function Indicators.

Additional file 2: Table S2. Function and System Indicators.

Additional file 3: Table S3. Kenyan actor scoring within functions.

Additional file 4: Table S4. Key discussion points from Kenyan actor scoring within functions.

Additional file 5: Table S5. Interaction scoring results.

Additional file 6. Discussions around actor interactions.

Additional file 7: Table S6. System performance indicators: key points from discussion around scoring.

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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 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 workshop with facilitation support from IR and KC. FW and KC interpreted the findings as presented in the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
All data generated or analysed during this study are included in this published article and its additional information files.

Declarations

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Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]CABI, Nairobi, Kenya. [2]CABI, Egham, UK. [3]CABI, Wallingford, UK. [4]Umma University, Kajiado, Kenya. [5]Ministry of Agriculture, Livestock, Fisheries and Cooperatives (Plant Protection Services Division), Nairobi, Kenya. [6]University of Nairobi, Nairobi, Kenya. [7]Kenya Plant Health Inspectorate Services (KEPHIS), Nairobi, Kenya. [8]Kenya Forest Research Institute (KEFRI), Nairobi, Kenya.

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