United Nations
Educational, Scientific and
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Botanists

of the twenty-first century

Roles, challenges and opportunities

Based on the proceedings of the UNESCO International conference *Botanists of the twenty-first century: roles, challenges and opportunities*

September 2014, Paris, France

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Quels botanistes pour le 21e siècle ?

Métiers, enjeux et opportunités

Basé sur les actes de la Conférence internationale de l' UNESCO
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Edited by Noëline R. Rakotoarisoa, Stephen Blackmore and Bernard Riera

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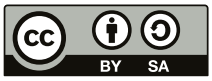

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Using information technology, communication and citizen science in alien invasive plant management in Kruger National Park, South Africa

Auteurs

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Abstract

Invasive plant species are a major threat to the biodiversity of protected areas and South Africa's Kruger National Park (KNP), which covers about 20 000 km^2, is no exception. The extensive river network draining highly invaded and transformed external catchments make KNP highly susceptible to alien plant invasion. Efficient control thereof requires early detection of alien species, increased awareness, effective eradication and dissemination of information amongst all relevant stakeholders. Pl@ntInvasive-Kruger was initiated to provide a platform and a range of tools in support of these actions locally by aiming to develop a suite of science-based, computer-driven tools for use by KNP managers, researchers and field teams involved in alien plant control. Four applications were developed, each supported by the global, multi-user PL@NTMANAGER database: 1) PUBLISH returns synthesised species information; 2) IDAO executes computer-aided plant identification; 3) IDENTIFY provides image recognition; and 4) CYBERTRAKER acts as an interface for mobile data collection applications. This toolkit facilitates the sharing of information between stakeholders, including scientists, field officers and citizens, and disseminates synthesised information to managers of invasive plants, eradication teams and conservationists. All tools are usable, or can be downloaded, from an internet based platform where members can also share information and documents and engage in discussions on alien invasive plants. Correct identification is an essential aspect of alien plant control programs, but is difficult and time consuming where large numbers of alien and indigenous plant species co-occur. The Pl@ntInvasive-Kruger database currently contains information on ~237 alien plant species, with the identification tools focussing on the 113 most important species. By facilitating the identification of invasive plants and supporting knowledge-

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sharing and the use of shared tools for a common goal, Pl@ntInvasive-Kruger promotes invasive alien plant control and thereby biodiversity conservation in KNP.

Résumé

Les espèces végétales envahissantes sont une menace majeure pour la biodiversité des aires protégées, et le parc national Kruger en Afrique du Sud (KNP) ne fait pas exception. La diversité de paysages et d'habitats et un réseau hydrographique qui draine des bassins versants très envahis à l'extérieur du parc rendent le KNP très sensible aux invasions par les plantes exotiques. Un contrôle efficace de cette menace nécessite une détection précoce des espèces introduites, avec en point-clé initial leur identification rapide et correcte, des méthodes appropriées de lutte, et la diffusion de données actualisées pour accroître la sensibilisation de tous les acteurs impliqués. Un projet de collaboration a été lancé pour soutenir ces actions. Pl@ntInvasive-Kruger fournit une plate-forme et une suite d'outils informatiques destinés à l'usage des gestionnaires du KNP, des chercheurs et des équipes impliquées dans la surveillance et le contrôle des plantes exotiques. Quatre applications ont été développées, toutes supportées par une base de données en ligne, multi-utilisateurs : 1) PUBLISH, permet de publier sur le Web les synthèses d'information sur les espèces; 2) IDAO, utilise l'identification des plantes assistée par ordinateur; 3) IDENTIFY, un système de reconnaissance automatique par image; et 4) CYBERTRAKER, une interface munie d'un processus d'identification simple. La base de données concerne actuellement près de 400 espèces de plantes exotiques, les outils d'identification mettant l'accent sur 113 espèces prioritaires. Cet ensemble d'outils a été développé d'une part, pour faciliter le partage d'informations provenant de différents acteurs tels scientifiques, agents de vulgarisation, équipes de terrain et citoyens, et d'autre part, pour améliorer la diffusion des ces informations aux intervenants chargés de la surveillance et/ou de la lutte contre les plantes envahissantes. Les outils sont utilisables ou téléchargeables, à partir d'une plate-forme collaborative Web où les membres peuvent également partager informations et documents, et organiser des discussions. Par son aide à l'identification des espèces et au partage d'informations, Pl@ntInvasive-Kruger contribue à promouvoir la conservation de la biodiversité du KNP et met en œuvre une approche nouvelle de travail où tous les acteurs apportent leur contribution à partir d'outils communs et dans un but commun, approche désormais essentielle pour la gestion des plantes envahissantes.

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Introduction

Since the 1950s, the growing influence of human activities has promoted the dispersal and establishment of species beyond their natural ranges. Often these alien species naturalise, proliferate and spread rapidly over large areas, and can have significant adverse effects to biodiversity (IUCN, 2012), the functioning of ecosystems (Vitousek et al., 1996; Mooney et al., 2005; Vilà et al., 2011) and on the health and economic well-being of human society (Pimentel et al., 2005). Invasions affect virtually all ecosystems and regions of the world, regardless of their status (Lonsdale, 1999) and protected areas, although created to protect natural or semi-natural environments, are not immune to invasions (Foxcroft et al., 2013). Reserves and national parks are affected by invasive species in temperate zones (Pyšek et al., 2002; Pauchard & Alaback, 2004; Allen et al., 2009) as well as in tropical and subtropical areas (Duffey & Usher, 1988; Tye, 2001; Foxcroft & Downey, 2008). In South Africa, 19 national parks have alien plant invasion as a management priority (Spear et al., 2011). Kruger National Park (KNP), spanning 360 km in latitude, contains diverse landscapes and habitats, is traversed by external rivers and is bounded by international borders and surrounded by mining activity, agriculture, private game reserves, cities and settlements. Internally, KNP hosts human residents and substantial tourism, further aggravating susceptibility to invasion by alien plants. The number of alien plant species has increased from six in 1937 to about 350 in 2013, with 81 species considered invasive / potentially invasive (Spear et al., 2113). In 1997 alien plants were recognized as a major threat to biodiversity in KNP, and are a management concern (Braack, 1997).

Control efforts have been funded through the National Working for Water Program (WfW) and South African National Parks (SANParks), and physical control operations, including mechanical, chemical and biological control, have been implemented (Foxcroft, 2003). To optimize the level of control achieved, an adaptive management strategy involving prevention, control and research was adopted in 2003 (Foxcroft & Richardson, 2003). This proactive approach to prevention seeks to avoid the introduction of new species to the park, whilst an early detection program aims to eliminate potentially invasive plants during early establishment. Spatially explicit data define invaded areas, and the extent and density of invasion, thus enabling appropriate management actions. At each step, the correct identification of species by the participants involved in the management program is paramount. Equally important is ease of access and availability of current species information. The ability of stakeholders within and beyond KNP (neighbouring areas, SANParks' other protected areas, and conservation programs elsewhere) to share data and knowledge of alien species, and management thereof, is key.

Spatially explicit data define invaded areas, and the extent and density of invasion, thus enabling appropriate management actions. At each step, the correct identification of species by the participants involved in the management program is paramount.

In KNP and immediate surrounds, different groups of stakeholders are involved in alien plant study, survey and management, including, amongst others, scientists and conservationists from SANParks and the South African Environmental Observation Network (SAEON), researchers from Universities, technicians and rangers from KNP, control teams from WfW, local municipalities, mining companies and survey teams from the Kruger to Canyons (K2C) UNESCO 'Man and Biosphere' program.

The objectives of Pl@ntInvasive-Kruger were therefore to 1) develop and implement a combination of tools providing species identification, access to species information and data-sharing, and 2) support the network of stakeholders involved in alien plant science and management in and around KNP.

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Methods

Species Identification

Currently KNP rangers and K2C technicians carry out daily environmental observations recording, *inter alia*, the location and abundance of invasive plants. For this they use palmtop computers (PDA) running a specific interface developed using CyberTracker (CT) software (MacFadyen, 2005). For species identification, field guides exist, but are not widely accessible and the species descriptions are often brief or absent. Further, such conventional plant identification tools are not always easy to use by both non-botanists or specialists, especially dichotomous keys (Le Bourgeois et al., 2004).

To overcome identification constraints various approaches, based on information and communication technology (IT&C), have been implemented since the 1970's. In response to needs identified by KNP managers, a revised CT version and two novel tools for plant recognition were proposed *viz*. IDAO (computer-assisted identification) and IDENTIFY (image recognition). These three applications each cover a standard set of 113 alien species that are either commonly found, or are of concern, in KNP (Foxcroft, 2003). The IDAO software initially development in 1995 and undergoing numerous upgrades (Grard et al., 1996; Le Bourgeois et al., 1996). IDAO constructs unknown candidate species in a step-wise manner from prominent characteristics selected by the user from schematic, multiple-choice menus (Le Bourgeois et al., 2008). Factsheets with descriptions and images are available for each species throughout the identification process. IDENTIFY assists users, through image-recognition analyses, with the identification of images of plants and their diagnostic features (Boujemaa et al., 2001; Yahiaoui et al., 2006). The software automatically compares photos submitted by the user with a reference image library, and returns the most similar images and corresponding species names. Based on user input, the CyberTracker identification module initially categorises species by life form; thereafter species are identified from the relevant subset of images and written descriptions.

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Unlike conventional dichotomous keys, IDENTIFY and especially IDAO do not prescribe the sequence in which characters, or images, are considered by users, and the 'percent similarity' output is tolerant of errors. All three identification tools rely almost exclusively on the observational skill of the user, rather than on specific knowledge or botanical training, and are fun to use. The functionality and efficiency of each application was evaluated through systematic identification tests conducted during workshops held in KNP, during June and July 2013, with participants from SAEON, SANParks, WfW, K2C and Palabora Mining Company (PMC). Evaluation focused both on 1) technical aspects (time to, and accuracy of, identification) and 2) 'user-friendliness' (e.g. perceived ease of use; importance of prior experience or education; personal or job relevance). In addition to tools being assessed for technical efficiency, participants scored them according to the interface and navigation process, the informative nature of text, supporting imagery and the need and value of the tool in identifying alien plants in KNP. Participants also answered open-ended questions about the advantages and disadvantages of each tool, and were given opportunities to suggest improvements. A total of 59 participants identified 217 plant samples using 23 plant species.

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Results

Accuracy of species identification

All three applications, IDAO, IDENTIFY and a customised CyberTracker database for alien plants in KNP have been made available for free download or online use from the participatory platform at http://community.plantnet-project.org/pg/groups/561/plntinvasivekruger/.

The average success of species identification was 76.4% (166/217), varying by application from 67.9% (57/84) for CT, 75.8% (47/62) for IDENTIFY and 87.3% (62/71) for IDAO. Time to identification ranged between 1-31 min, with an average of 8 min and a median of 6 min. Identifications were approximately twice as fast using CT than with the other two tools, with IDAO requiring marginally more time than IDENTIFY. Irrespective of the tool used, correct identifications required less time, on average, than incorrect identifications. After 25min the identification was usually incorrect.

Overall the tools were considered by 30% of the respondents as 'very easy' to use, 'easy' by 34.2%, 'moderately easy' by 22.8% and 'difficult' by 5.1% of the participants. Participants considered CT easier to use (85% 'very easy' or 'easy' ratings) than either IDAO (69%) or IDENTIFY (62%). However, this distinction was much less pronounced for specialists/scientists than for technicians. For the latter stakeholder group, IDENTIFY was seen as the most difficult application to use.

The visual interface of the tools were rated mostly as excellent or good, but with more mixed opinions for CT. The navigation process was described mostly as excellent or good; CT was the most popular tool whilst IDENTIFY was considered the most difficult to navigate. For IDAO and IDENTIFY, reference images were highly appreciated, whilst for CT, they were considered to be too few and of poor quality with no option for enlargement due to the PDA specifications. Written descriptions in CT and IDAO were consulted by most participants to confirm image- and observation-based identifications.

All participants considered the tools relevant to alien plant control in and beyond KNP, either in their current version (especially IDAO), or with some refinement (especially for CT). Further, 95% of participants felt that the utility of each tool in KNP, or surrounding environments, could be improved by incorporating additional species, especially where confusion with native species is likely.

Accessibility of species information

Descriptive factsheets for each of the 113 test species, including nomenclature, collector, locations and collections (e.g. images, herbaria) were managed through Pl@ntInvasive-Kruger's online, multi-user database using a derivative of the Pl@ntNet DATAMANAGER application (http://community.plantnet-project.org/pg/groups/5320/plntnetdatamanager/). The various stakeholders with access to the database, who function collectively as a network, can access, and importantly also update, databased information at any time based on current field observations or learning. Each species-specific module is populated with a general description, vernacular names and other detailed information on, *inter alia*, growth form, cotyledons, aerial organs and seeds, biology, ecology, origin and distribution, level of invasiveness and documented control methods, and possibly confusion with, in particular, similar native species. Further, nearly 5000 supplementary photos, collected either during the project or sourced from institutional

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libraries, have been indexed and incorporated into the database and reflect 100 of the 113 test species. A factsheet of combined information and imagery exists for each species and is published in html format (http://publish.plantnet-project.org/project/plantinvasivekruger) through the PUBLISH application developed by Pl@ntNet.

Data- and knowledge-sharing between stakeholders

Average identification times, which are currently quicker than those reported by Morse et al. (1996), will improve further as users become accustomed to and can navigate the tools more freely.

The launching page of the participatory web platform of Pl@ntInvasive-Kruger falls within the broader Pl@ntNet platform developed under ELGG 1.7, an open-source social networking engine (Elgg Foundation, 2012). The platform allows all members to communicate, sharing scientific documents, technical papers, protocols, theses or reports and bookmarks of websites of interest. This is particularly valuable for documents lodged with host institutions, but which are not widely accessible via the internet. Further, embedded tools such as the calendar, blog and forum facilitate networking and collaboration between stakeholders and the sharing of ideas, observations and images. This is especially useful where photos of an unidentified plant are uploaded to the platform, so soliciting inputs and benefitting from the collective expertise of the member community. Likewise, any document, photo or information posted on the platform can be commented on and discussed amongst members. The platform also serves as the main point-of-access for the IDAO, IDENTIFY and CT identification applications, as well as the DATAMANAGER database and synthesised species information via the published html factsheets.

Discussion

The average identification accuracy (76.4%) achieved when assessing the efficacy of the tools developed by Pl@ntInvasive-Kruger falls within the range reported for other automatic or semi-automatic identification tools for various organisms and animal and plant structures (Gaston & O'Neill, 2004). The user-driven IDAO tools' performance of ~87% is very satisfactory, surpassing IDENTIFY (~76%) and being substantially higher than CT (~68%). The ability to detect an error contributes to a tools' utility. For example, using CT as an identification tool, with the lowest accuracy and ability to detect misidentification, CT should only be used as a first step to identification, which should then be confirmed using complementary Pl@ntInvasive-Kruger tools or other reference materials. CyberTracker is therefore best suited to data collection and less reliance as an identification application, especially given the relatively poor botanical training that is typical of field monitors and control teams.

Average identification times, which are currently quicker than those reported by Morse et al. (1996), will improve further as users become accustomed to and can navigate the tools more freely. This is particularly true where participants have little or no experience using computers, as was the case with several participants here. Contrary to Morse et al. (1996), times were quicker for the correct, rather than incorrect, identifications. Further, participants in the Pl@ntInvasive-Kruger project displayed more confidence in their computer-assisted identifications when they were correct, compared to both Morse et al. (1996) and Goëau (2012).

Having images of plant habit and morphological characteristics available in IDENTIFY for consultation by users proved to be a key element in successful identification using both CT and IDAO. However, the lower accuracy of the IDENTIFY tool compared to IDAO suggests that greater efficacy is achieved when the user engages with the computer application and combines images (photos and line drawings)

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and text, rather than by relying on user-independent image recognition software. In particular, combining different information formats may help users recognise errors and confirm doubtful identifications.

Workshop participants all showed great enthusiasm for the Pl@ntInvasive-Kruger tools (*participant comment – "I like everything!!! CyberTracker, IDENTIFY and IDAO!"*). Such comments highlight a need to provide assistance with identification and accessible information to stakeholders working on alien plants and their control in KNP and neighbouring areas. Critically, the tools enable the user to access free information and identify unknown alien plant species independently, providing motivation and a sense of empowerment. Users of the three tools are stimulated to develop their botanical and scientific knowledge, and their computer skills (*participant comments – "Adding more species will be good because we can learn more", "We would like to learn how we can use the computer"*). Previously, access to information and resources such as identification tools has been restricted, particularly to field teams and technicians, who were dependent on their superiors or professional colleagues for identification. Critically, this hinders the implementation of management interventions should suspected alien species be encountered in the field. The ability to act quickly, and with confidence, is essential for teams monitoring, and managing, invasive alien plants. Participants also appreciated the complementarity of the tools, and would combine their use; CT in the field, and IDAO and IDENTIFY in an office at work, or at home. Further, using the tools in combination with the participatory platform provides opportunities for engagement between stakeholders, and augments the central database through the sharing of field data.

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