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Does vegetation structure influence criminal activity? Insights from Cape Town, South Africa

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Abstract. Dense vegetation, especially thickets of trees or shrubs, has been associated with actual and perceived crime risk in several parts of the world. In some contexts, invasive alien trees and shrubs can create a habitat structure that is very different from that provided by native vegetation. The role of alien and native plant species at different stages of invasion/densification in mediating criminal activity within a managed landscape remains poorly documented and elaborated. Using the South African city of Cape Town (a rapidly growing metropolitan centre within a global biodiversity hotspot) as a case study, we discuss the role of alien, invasive and native vegetation in mediating criminal activity in urban areas, particularly in a developing-country context. We argue that the incidence of crime may not always be determined by the biogeographical status of dominant plants (i.e., whether vegetation is dominated by native, alien, or invasive alien species), but rather on the structure/habitat they provide. A stronger link between crime and vegetation is likely in areas where tree invasions have drastically altered vegetation structure. This paper draws attention to a novel interaction between humans and vegetation and highlights the need for context-specific approaches when managing plant invasions, particularly in urban areas.

Keywords: Biological invasions, management, safety and security, tree invasions, urban invasions, vegetation structure.

INTRODUCTION

Urbanization is increasing rapidly worldwide. The resulting increases in human population density places considerable strain on the functionality of ecosystems and the services they provide, challenging the resilience of urban environments (Elmqvist et al. 2013). A by-product of urbanisation, particularly in developing countries with complex socio-political histories and limited resources, is an increase in criminal activity. While many strategies for crime prevention focus on increased surveillance and harsher penalties for infringements, physical and social aspects of the environment are well known to facilitate or mitigate criminal activity (Brantingham and Brantingham 1991, Eck and Weisburd 1995, Lersch 2007).

There are two contrasting schools of thought regarding the association between vegetation features and criminal activity. The first, more recent, view posits that the presence of vegetation potentially deters crime. The second holds that vegetation facilitates

crime because it provides cover, and therefore hiding opportunities for criminals. Kuo and Sullivan (2001) suggest that high-canopy trees and other forms of low-stature vegetation (e.g., grassy areas) do not promote crime, but rather deter it by increasing visibility and thus options for surveillance. Well-designed and managed green spaces promote social inclusion, elevate public spirit and local pride (Gaston 2010), although this may depend on the local community context. Such green spaces may be associated with high perceived personal safety and can decrease crime by attracting people to spend time outdoors (Kuo et al. 1998, Kuo 2003). The presence of more people in these spaces means that it is harder for criminals to escape attention, resulting in an informal system of surveillance (Kuo and Sullivan 2001). A caveat to these studies is that under some circumstances, the presence of vegetation – particularly vegetation perceived as being overgrown or that obstructs views – can generate negative reactions and feelings

of insecurity (Brownlow 2005). For many people, uncontrolled plant growth and secluded spaces instil a sense of fear in urban landscapes (Nasar and Fisher 1993, Kuo and Sullivan 2001). Several studies have suggested that low, dense vegetation is associated with actual or perceived crime risk because it provides criminals with hiding places (Fisher and Nasar 1992, Nasar et al. 1993).

Vegetation is also thought to play a more indirect role in facilitating crime by serving as an indicator of (a lack of) social control over the environment. The “broken window theory” suggests that neighbourhoods displaying visual cues of neglect, disorder or poor maintenance experience more crime because such cues suggest to criminals a lack of effective law enforcement (Wilson and Kelling 1982). Overgrown vegetation may also increase people’s fear of crime and elements of wildlife that are perceived as dangerous (e.g., snakes).

Perceptions of urban green space differ among urban residents (Bogar and Beyer 2016). There is often a contradiction in that some people may prefer green spaces as their surroundings, yet these same spaces also instil a fear of crime in others (Jorgensen et al. 2005). Green spaces can provide recreation opportunities for urban residents (Shanahan et al. 2015), enhance feelings of safety, and are important components of a “sense of place” for many urban residents. However, other residents may perceive green space (especially unmanaged spaces) as areas which harbour crime and violence. Perceptions of such spaces are influenced by many factors including the degree of management and the socio-economic context. For example, although poorly managed public parks may invoke a sense of fear in some residents due to overgrown vegetation and lack of effective law enforcement (Jorgensen 2004, Jorgensen et al. 2007), the same conditions may create recreational opportunities for others (e.g., shade or bird watching) which in turn provide opportunities for criminal activities. Perceptions of green spaces may also change based on personal experiences or knowledge of criminal incidents associated with particular spaces. This can lead to residents limiting their use of or avoiding such spaces altogether (Jorgensen et al. 2002, Michael et al. 2001).

These contrasting theories regarding vegetation and crime suggest that the type or configuration of urban vegetation matters as does the context (e.g., socio-economic) in which the vegetation is occurring. Few studies showing a relationship between vegetation and crime are explicit about the characteristics of vegetation being studied (e.g., species, height, age, density). Complexity in vegetation structure is vital for wildlife as it provides shelter, connectivity and foraging opportunities (e.g., Brearley et al. 2010). The same vegetation features may indeed be utilized in the same way by humans engaged in criminal activities.

In an increasingly urbanised world, urban biodiversity and ecosystem services (ES) are threatened by the proliferation of anthropogenic features such as the expansion of urban areas and other types of land cover change, but also by invasive alien plants (IAPs) (Aronson et al. 2014, Zhou et al. 2015). Many alien

plant species are introduced into urban areas to provide ES (e.g., aesthetic enhancement or food provision). Some of these alien species become invasive, and have negative impacts on existing ES, in the process creating novel ES and/or ecosystem disservices (EDS) (Potgieter et al. 2017). These impacts include effects on public safety and security such as increased fire risk and criminal activity (e.g., van Wilgen et al. 2012). For example, *Arundo donax* L. (Poaceae; giant reed) which has invaded the banks of the Rio Grande River along the Mexico-USA border provides dense cover for drug smugglers and illegal crossers and impedes line of sight for law enforcement officials (Aguilar 2016, Goolsby et al. 2016).

The nature of plant invasions (e.g., forming dense stands on vacant lots) can create a habitat structure that is very different to that provided by native vegetation (Fig. 1; van Wilgen and Richardson 1985, Richardson and Cowling 1992, Le Maitre et al. 2011), and such changes can serve as an indicator of neglect, disorder or poor maintenance. Similarly, colonisations by native plants can lead to the formation of dense stands on vacant land which could also serve as an indicator of neglect. However, areas invaded by alien plants which grow significantly taller and denser and are more resilient to human-mediated disturbance compared to the native plants, can provide diverse new opportunities for those engaged in criminal activities (Gaertner et al. 2016).

Invasive plant species promoting criminal activity have been reported in many rural contexts, particularly in South Africa. In their study of the role of invasive alien species in rural livelihoods in the Eastern Cape, South Africa, Shackleton et al. (2007) found that some villagers deemed the invasive tree *Acacia mearnsii* De Wild. (Fabaceae; black wattle) undesirable as they feared possible attack or rape from criminals hiding in dense wattle stands. Similarly, rural communities in the Drakensberg region of South Africa perceived *A. dealbata* A. Cunn. (Fabaceae; silver wattle) and *A. mearnsii* negatively as these alien tree species provide cover for thieves and criminals (de Neergaard et al. 2005). Invasive stands of alien mesquite trees (*Prosopis* species; Fabaceae) in some rural villages in South Africa’s Northern Cape Province also provide refuge for criminal activities (Shackleton et al. 2015).

While several studies have explored the link between urban flora and criminal activity (e.g., Kuo and Sullivan 2001, Donovan and Prestomon 2012, Wolfe and Mennis 2012), few have explored whether the biogeographical status of these plants is a significant factor, or whether vegetation structure is a key factor mediating criminal activity. Furthermore, analyses of the association between vegetation and criminal activity have focused almost exclusively on large US cities, leaving unexplored the role of vegetation in facilitating crime in cities of developing countries and in many shrinking cities in developed countries.

Developing countries face particularly complex challenges as a lack of resources and capacity directly results in negative environmental consequences and socio-economic impacts (Piracha and Marcotullio 2003).

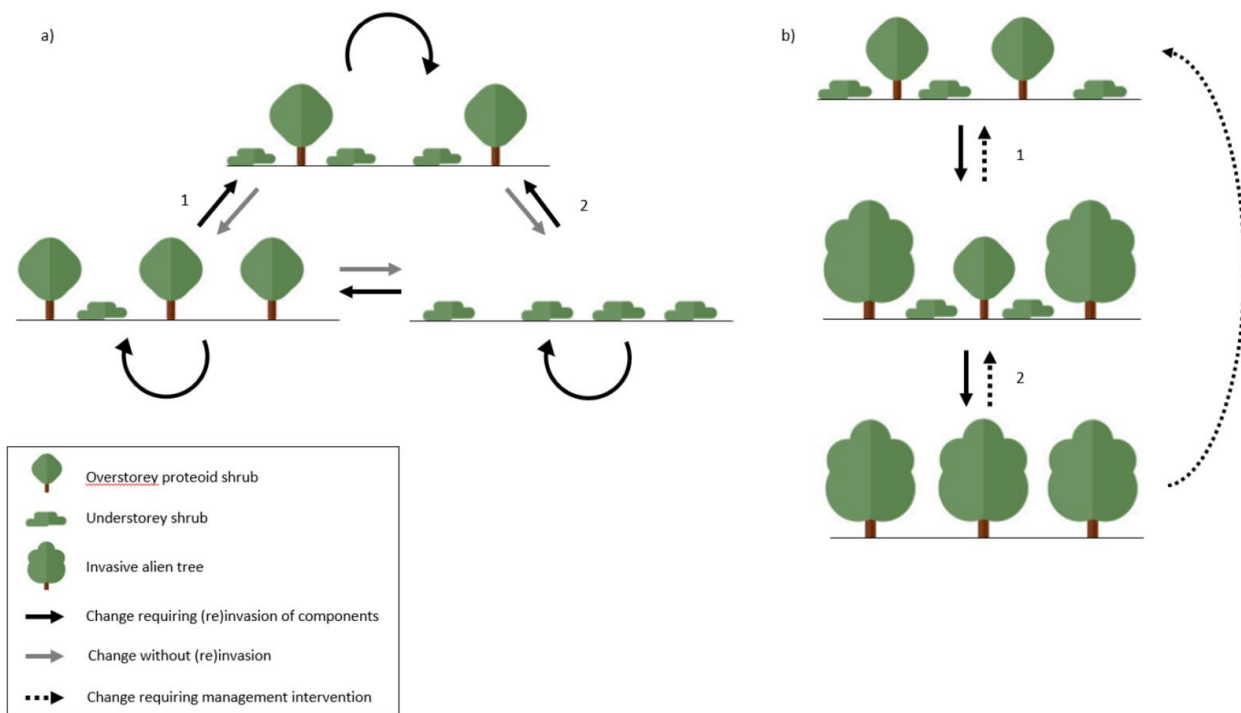


Figure 1. Schematic representation of disturbance-induced changes (e.g., fire) in the structure of native fynbos vegetation in (a) the absence of invasive alien trees, and (b) invaded by alien trees (inspired by Richardson and Cowling, 1992). In the absence of invasive alien trees, recruitment of overstorey shrubs (predominantly a proteoid component) is highly variable. They may proliferate and suppress understorey species (a1). Adverse conditions during or after a disturbance event may result in poor recruitment or local exclusion of overstorey shrubs (a2). Once invasive alien trees (such as Australian *Acacia* species) are established in fynbos communities, their resilience to disturbances disrupts the natural successional processes. As the invasive alien trees proliferate (b2), they outcompete native species and alter the vegetation structure. Management interventions (dashed lines) are required to return the system back to the native state. CBA - Critical Biodiversity Area; ESA - Ecological Support Area (ESA); OESA - Other Ecological Support Area

We used questionnaire-based surveys, and analysed court cases to examine the relationship between vegetation and criminal activity. Using the South Africa city of Cape Town (a rapidly growing metropolitan centre within a global biodiversity hotspot and a developing country) as a case study, we argue that a stronger link between crime and vegetation is likely to occur in areas (such as the Cape Floristic Region) where alien tree invasions have drastically altered vegetation structure.

METHODS

Case study: Urban vegetation and crime in Cape Town

Located at the southwestern tip of Africa within the Cape Floristic Region (CFR), a globally recognized biodiversity hotspot, and covering an area of 2460 km², the city of Cape Town (hereinafter referred to as Cape Town or ‘the City’) has a population of 3.8 million people (Holmes et al. 2012). The City is home to 19 of South Africa’s 435 nationally recognized vegetation types and hosts 52% of the country’s critically endangered vegetation types (Rebelo et al. 2011;

Fig. 2). The dominant natural vegetation in the area is fynbos, a short shrubland vegetation type that grows on infertile soils and displays various adaptations for persistence in a fire-prone environment. Native trees are scarce in remaining natural vegetation (Richardson and Cowling 1992, Rundel et al. 2014), and native forests (Fig. 3a, scenario 3) only cover about 3% of the area of the City (Cowling et al. 1996).

The City has a long history of European colonization and associated introductions of alien plant species (van Wilgen 2012, Pooley 2018). Many alien plant species have spread into the natural and semi-natural vegetation where they have a negative impact on ES provision and human well-being (van Wilgen et al. 2008). Despite substantial attempts to control IAPs, they remain embedded in the landscape. Invasions by tall alien trees and shrubs have drastically altered the vegetation structure (Fig. 1), negatively impacting on existing ES, and creating novel ES and/or EDS (Gaertner et al. 2016).

As a legacy of the apartheid regime, Cape Town remains highly divided, both socially and spatially (Swilling 2010), in the form of race-based residential

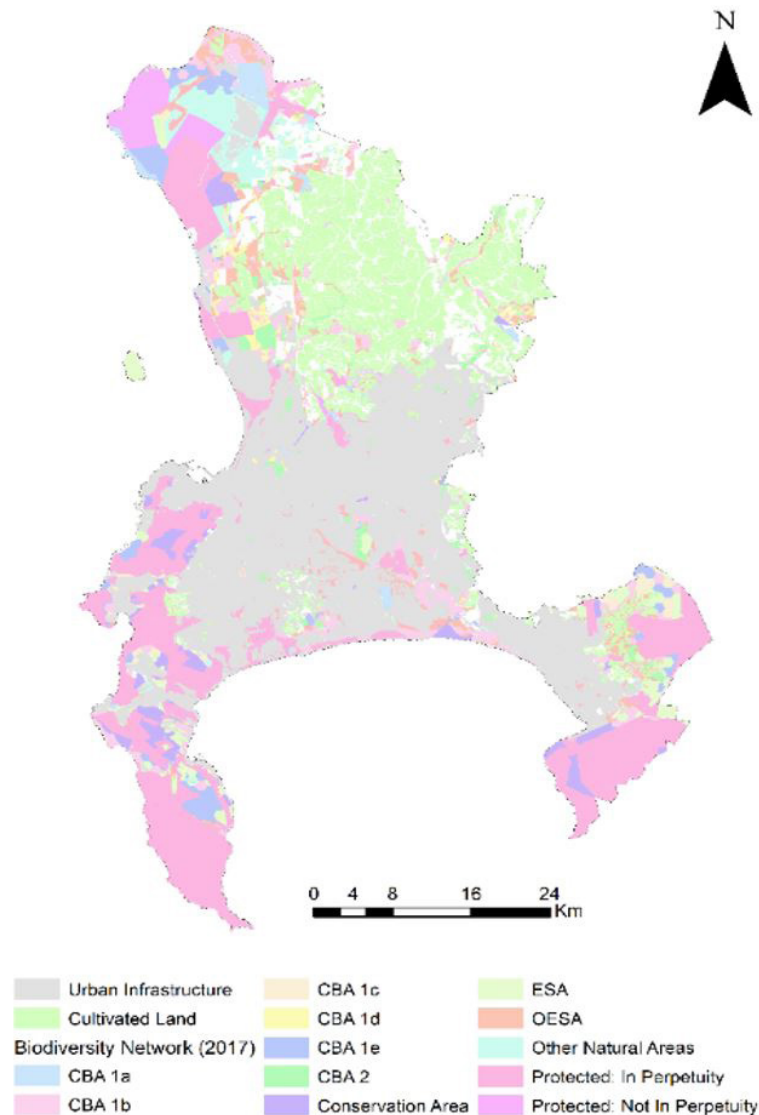


Figure 2. The city of Cape Town municipal boundary showing urban infrastructure, cultivated land and the City's Biodiversity Network.

segregation. Migration to the City has resulted in rapidly expanding informal settlements that were initially established during the previous century and enforced through apartheid planning. These are mostly located along the outskirts of the City and are home to the poorest, most marginalized urban populations. Many of these communities lack access to basic services and amenities like electricity, sanitation, waste disposal, and water (Graham and Ernstson 2012). The provision of education, housing, nutrition and healthcare, and transport infrastructure remain major socio-economic challenges in the City (Goodness and Anderson 2013). High levels of poverty and unemployment, a propensity for violence, drug and alcohol abuse and moral decay within many communities, combined with a criminal justice system that is ineffective in many respects, result in exceptionally high levels of crime (Kruger and Landman 2008).

Cape Town's crime statistics highlight a major challenge for the City and its residents. The City experienced the highest overall crime rate of all South African metropolitan areas in 2014/15 (CoCT 2016a). This has been attributed to a significantly higher rate of drug-related crimes, coupled with relatively high rates of property crime compared to other South African cities. In terms of violent crime, Cape Town continues to experience the highest incidence of murder, attempted murder, sexual crime and common assault crime, and the highest rate of robbery with aggravated circumstances of all South African cities (CoCT 2016b).

Socio-political status

Current socio-economic factors in South Africa and the history of forced segregation have resulted in a distinct relationship between crime and the physical environment. Despite many interventions

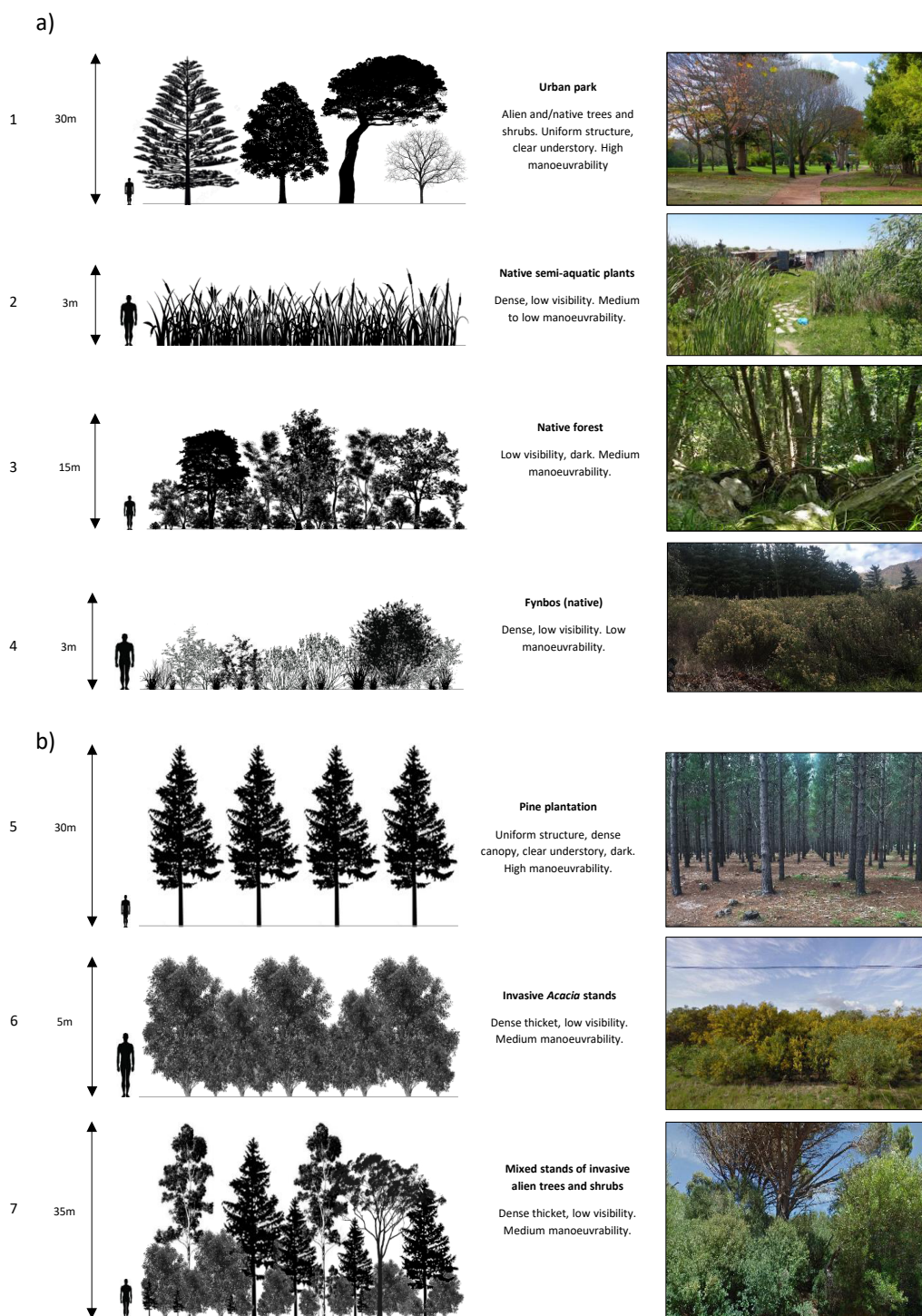


Figure 3. Conceptual scenarios of vegetation structure involving (a) alien and/or native and (b) alien invasive plants across Cape Town.

and huge efforts over the last two decades, the form and structure of Cape Town as an apartheid city has remained largely unchanged. Apartheid policies of the past still contribute to disproportionate levels of crime in different communities (Kruger and Landman 2008). Crime patterns and trends differ substantially

between affluent suburbs and poorer areas such as townships and informal settlements (Lemanski 2004). Crime levels are highest in poorer communities where there is a general lack of resources, and where infrastructure is poorly developed. Residents in lower income areas are subjected not only to higher levels

of violence in terms of property crimes, but also to interpersonal crimes such as assault, murder and rape (Shaw and Louw 1998).

Australian *Acacia* species were introduced in the mid-nineteenth century to stabilize the mobile sands on the low-lying, biodiversity-rich dune fields to the north and east of Cape Town, known as the Cape Flats (Anderson and O'Farrell 2012, Donaldson et al. 2014, Pooley 2018). In the mid-twentieth century, under apartheid spatial planning, people of colour were forcibly removed from the central areas of Cape Town and relocated on the urban edge to the north and east of the City. Many were forced to reside in the Cape Flats where Australian wattles had flourished (Kull et al. 2011). These communities were consequently forced to interact with a difficult ecology, and the rising poverty (the cause of which is complex and multi-dimensional; de Swardt et al. 2005) forged a strong association with crime and invasive wattles. Today, many reported crimes have been linked to Australian wattles (Cape Argus 2014, Roberts 2015, Serra 2017; Appendix A, Case Study 4), which are referred to colloquially as the 'bush of evil', particularly in low-income areas of the City (Rebelo et al. 2011, Holmes et al. 2012, Allsopp et al. 2014).

Vegetation structure

The juxtaposition of poorly-resourced human settlements with dense stands of invasive trees and shrubs around Cape Town can create novel opportunities for crime. Invasions that transform the native shrubland vegetation to dense thickets and woodlands of alien trees and shrubs can radically change the vegetation structure over large parts of City (e.g., van Wilgen and Richardson 1985). Alien trees and shrubs like Australian wattles (*Acacia* species) are more resilient to major human-mediated disturbances and can form dense thickets in a much shorter time, resulting in an increase in dense alien-dominated vegetation (Fig. 1). Despite substantial efforts to reduce the distribution and density of invasive alien trees and shrubs, dense stands (Fig. 3b, scenario 7) are becoming more common, especially at the urban-wildland interface. Furthermore, the structure of fynbos (Fig. 3a, scenario 4) is strongly influenced by the frequency of fires (Cowling et al. 1996). Very dense, relatively tall fynbos (persisting more than 10 years after fire) is becoming scarcer on the Cape Peninsula as the frequency of fires increases. Fynbos is quickly degraded in areas that are highly disturbed at the urban-wildland interface. For example, tall proteoid shrubs are easily eliminated by fires at short intervals or by harvesting for wood (Fig. 1a). However, alien trees and shrubs like Australian wattles are extremely resilient to changes in fire frequency and harvesting pressure and can form dense, often impenetrable thickets in a much shorter time after fire; even fires at the shortest possible interval will not eliminate the stands but just make them denser (Gaertner et al. 2014; Fig. 1b). Certain native species,

such as *Typha capensis* Rohrb. (Thyphaceae), are also expanding in some areas due to human-mediated disturbances and now play an important role in facilitating criminal activity (Fig. 3a, scenario 2; Appendix A, Case Study 2).

Data collection

Crime statistics

To assess the number of criminal incidents linked to vegetation across the City, we searched the South African Legal Information Institute (SAFLII) database and identified all case judgements (~4300 cases) handed down through the Western Cape High Court (Cape Town) from 1993 to 2017 and the Constitutional Court from 1995 to 2017 (see Online Appendix C for further details on the methodology). Our search and examination of ~4300 court cases yielded only eight cases in which a criminal incident was directly associated with vegetation – three of these cases occurred within the City's municipal boundary. While these findings do not suggest a causal relationship between crime and vegetation, this does not necessarily mean that features of the vegetation do not play a role in the criminal act. Moreover, a comparative assessment of criminal cases *not* associated with vegetation may not be useful. Besides the limitations associated with reporting bias, reported criminal incidents seldom contain information about the surrounding vegetation unless there is a direct causal link (such as in cases presented in the Online Appendices). Such information is typically not deemed important in the context of the case.

Manager's perspectives

To explore the role of vegetation in facilitating criminal activity in Cape Town's formally managed green spaces (e.g., nature reserves and other conservation areas), we conducted a questionnaire-based survey (available in English only) with land managers from two leading conservation authorities responsible (either directly or indirectly) for managing IAPs in Cape Town (the City's Biodiversity Branch and the Working for Water (WfW) programme). The questionnaire was developed using Google Forms¹ and distributed in May 2018. The questionnaire consisted of five questions which sought to identify the respondent's employment position, their area of responsibility, and their experiences with criminal activity and vegetation (native and alien/invasive) (see Online Appendix B). The questionnaire included a combination of closed- and open-ended questions. Incidence of vegetation-related crime recorded in the participants' responses were grouped according to the nature reserve crime categories from the City's Biodiversity Branch. Electronic surveys are limited to those with access to a personal computer, email and internet access. To counteract this bias, telephone interviews (based on the questionnaire) were conducted with participants with limited online access.

¹ (<https://docs.google.com/forms>)

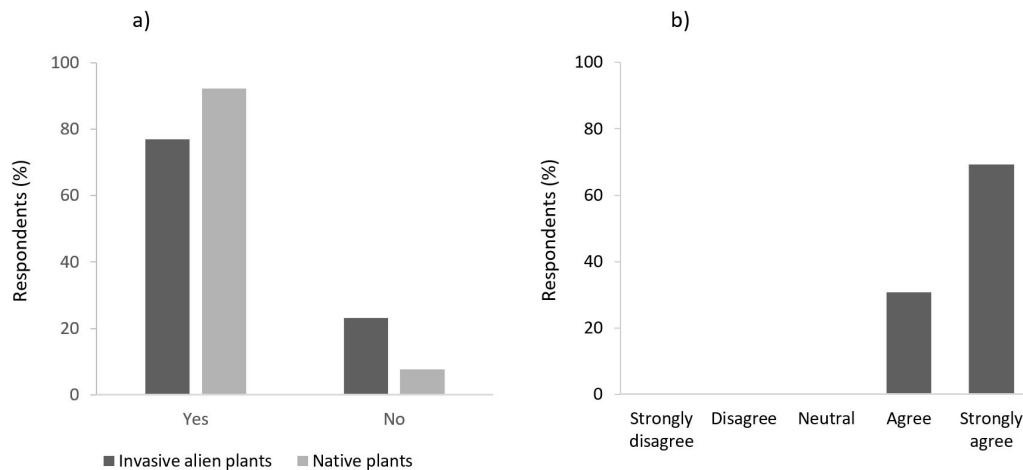


Figure 4. Conservation managers' views on the association between criminal activity and vegetation in Cape Town, South Africa. Respondents were asked whether (a) they were aware of any safety and/or security risks associated with invasive alien and native plants, and (b) criminal activity occurs in both native and invasive vegetation, and whether the vegetation structure the ultimate factor facilitating criminal activity.

Table 1. Number of vegetation-related crime incidents mentioned by respondents in the online questionnaire surveys for native plants species and invasive alien plant species (grouped according to the nature reserve crime categories from the City of Cape Town Biodiversity Branch) (t-value = -2.54; $p < 0.01$).

Crime category	Number of incidents	
	Native plants	Invasive alien plants
Breaking and entering	2	3
Damage to infrastructure	1	0
Dead body*	0	2
Drug use	2	3
Illegal dumping	2	5
Illegal structures	2	3
Illegal trade /collection of fauna	2	3
Illegal trade /collection of flora	1	2
Muggings	0	4
Prostitution	1	2
Rape	1	1
Theft	2	8
Trespassing	4	8
	20	44

*The presence of bodies is not always the result of a criminal act but is included based on the context of manager's responses.

RESULTS

Our online questionnaire yielded 15 responses from conservation managers around the City. Most respondents (77%) associated safety and/or security risks with IAPs in their area of responsibility, but 92% also associated such risks with native plants (Fig. 4a). All respondents agreed (69% strongly agreed and 31% agreed) that crime can occur in vegetation dominated by both native and IAPs, and that vegetation structure is the ultimate factor facilitating criminal activity (Fig. 4b). However, a paired-sample t-test showed a significant

difference in the number of cited criminal incidents associated with IAPs (44 incidents from 12 categories) than with native plants (20 incidents from 11 categories) ($p < 0.01$; Table 1). As the average density (% cover) of IAPs for protected areas within the City boundary is only 7%, this finding becomes more significant.

Half of all respondents (50%) cited *A. saligna* (Labill.) H.L.Wendl. (Fabaceae) to be associated with criminal activity. Other IAPs mentioned included *A. cyclops* A.Cunn. ex Don (Fabaceae) and *A. longifolia* (Andrews) Willd. (Fabaceae), *Eucalyptus* spp. (Myrtaceae) and *Pinus* spp. (Pinaceae). Most commonly cited crimes



Figure 5. Examples of vegetation associated with criminal activity. **(a)** The scene of a violent crime incident where the victim's body was discovered in dense native fynbos vegetation (Photo: L. Knipe); **(b)** Illegal dumping of waste in dense *Acacia saligna* stands (Photo: L.J. Potgieter); **(c)** Abalone poachers hide their catch in native fynbos vegetation (Photo: W. Witte); **(d)** The alien tree *Quercus robur* L. (Fagaceae) used to gain access to a first-floor parking lot where vehicles are regularly broken into (Photo: L.J. Potgieter); **(e)** *Acacia saligna* stands are used as cover for prostitution (Photo: L.J. Potgieter).

associated with IAPs were theft, trespassing, illegal dumping (Fig. 5b) and muggings, and for native plants were trespassing, illegal infrastructure, illegal dumping and theft (Table 1).

DISCUSSION

We do not suggest that vegetation causes crime, but rather provides opportunities to commit crime. Vegetation structure may indeed determine the type of

crime committed. For example, someone considering carrying out a violent crime such as murder would seek taller, denser vegetation to conceal the criminal act, while the open nature of managed urban parks (Fig 2a, scenario 1) may only see opportunistic crime such as muggings or vandalism. Different vegetation structures may also play different roles in the execution of criminal acts. For example, a perpetrator may use an urban park to gain access to residential houses

to carry out a burglary. Specific plant traits may also influence the likelihood and type of crime being committed. For example, vegetation dominated by thorny shrubs is less likely to be used by criminals (D. Gibbs pers. comm.).

The interaction between criminal activity and vegetation does not always occur in isolation and can be influenced by other features of the landscape which aid in facilitating crime and may also determine the type of crime committed. Criminal activity is unevenly distributed across the urban landscape and is facilitated or limited by physical features of the landscape. Topographical features such as hills, water bodies and rivers can influence the incidence of crime in specific areas. For example, hills or dunes can be used to conceal illegal poaching of marine wildlife (Fig. 5c), and rivers can be used as routes to gain access to targeted sites. Furthermore, the location of sites in relation to specific land uses and access routes (e.g., major highways) determines the site's accessibility, privacy, and ease of escape (Brantingham and Brantingham 1978).

Management challenges

The following challenges are discussed in the context of Cape Town, South Africa. Many of these challenges may be unique to the City, but should nonetheless be explored in different contexts, ecoregions, and across different taxa.

Factors relating to safety and security have been identified as crucial features influencing the selection of invaded areas for management within Cape Town; these factors clearly need to be considered when planning for biodiversity conservation in general (Potgieter et al. 2018). Coordination and implementation of IAP control efforts across the City has, however, been largely *ad hoc* and interventions are only initiated when funding becomes available (Irlich et al. 2017). For example, when crime incidence associated with vegetation increases in certain areas, local communities demand the clearing of dense vegetation, resulting in the allocation of funds. In the absence of management interventions by municipal authorities, communities opt to control problematic vegetation themselves (e.g., Abrahams 2013). Highlighting the need and importance of these efforts, in areas where crime has become a problem, can provide extra incentive and focus for IAP management activities.

Land parcels in urban environments are smaller and more numerous compared with rural areas and can fall under the jurisdiction of many landowners (e.g., privately-owned property, national and provincial government land, municipal property managed by different departments). This makes coordination of activities challenging as landowners have different incentives, policies, priorities and approaches for managing IAPs (Gaston et al. 2013, Irlich et al. 2017). Consequently, many land parcels may be neglected or poorly managed, often resulting in the establishment and proliferation of IAPs. In Cape Town, well-managed vegetation remnants generally support relatively low-stature vegetation, whereas unmanaged remnants have old,

dense stands of fynbos or are invaded by alien trees which grow taller than the native vegetation, thereby providing opportunities for crimes to take place (Fig. 5d). This is more likely to occur in the lower-income areas, as limited resources for environmental management purposes are directed disproportionately towards more affluent areas (Lemanski 2007). Therefore, effective vegetation management can contribute to reducing criminal activity in local areas. While not ecologically sustainable, a short-term solution that managers may need to consider (at least in the context of Cape Town) is to cut old stands of fynbos at regular intervals to prevent opportunities for crime to take place.

Planning and managing vegetation in urban green spaces presents further challenges. For example, urban park users may avoid areas with poor lighting and dense vegetation (Madge 1997) but managing such vegetation to combat safety concerns not only presents additional costs but risks a reduction of associated ES such as habitat provision (Jansson et al. 2013). Furthermore, once vegetation is managed, increased maintenance problems (such as regular pruning of low-hanging tree branches) are likely to emerge.

Severe levels of poverty and inequality add to the complexity of developing crime prevention strategies and the implementation of appropriate responses aimed at reducing crime. For example, in many townships and informal settlements around Cape Town, poor infrastructure, electricity and water services forces residents to travel some distance (mostly on foot) to access toilets. Many residents fall victim to crime during this activity, especially at night. City managers must make many decisions on how to allocate and prioritise funding for aspects such as increasing levels of surveillance in the area, improving lighting, supplying additional toilets, and managing the vegetation which may be facilitating or exacerbating criminal behaviour.

Limitations and the way forward

Responses from our questionnaire survey and discussions with conservation managers suggest that the role of vegetation in facilitating crime is a major issue and that the magnitude of the problem has been significantly underestimated. However, many key questions regarding the link between vegetation and crime are difficult to answer through empirical research. Such questions include: Is the link between crime and vegetation merely coincidental or is there a causal relationship? Do features of the vegetation facilitate crime, or do they change the dimensions of crime? Does the clearing of dense vegetation in crime hotspots ultimately reduce the incidence of crime, temporarily deter it, shift the location of incidents, or does it have no effect? Does vegetation structure determine the nature of the crime committed? Can the removal of dense vegetation in crime hotspots affect the types of crime committed? What interventions are needed to curb criminal activity in these areas?

Difficulties in quantifying local-scale crime occurrence and vegetation (native and alien/invasive) age and density at the city-scale complicate testing for a causal relationship between crime and vegetation.

The steep socio-economic gradient in many urban areas, especially in developing countries (such as Cape Town), suggests that the association between crime and vegetation is likely to differ substantially within and between neighbourhoods of different socio-economic classes. Urban environments are dynamic systems, and both crime and vegetation change considerably over space and time. Additional challenges include poorly maintained police records which are seldom easily accessible. Given these challenges and limitations, an experimental, multivariate approach may not be feasible.

Access to information on criminal activity is limited to what is reported, and the types of associated crime may have not met the threshold required for reporting; there is generally a bias towards extreme and atypical offences in terms of reporting frequency (O'Connell 1999). For example, criminal incidents occurring in informal green spaces in poorer neighbourhoods (which receive little to no management) are less likely to be reported than incidents occurring in formal, managed green spaces such as national parks or nature reserves.

Long-term, transdisciplinary studies on crime incidence and vegetation changes across the socio-economic gradient using a range of approaches are needed. It may be more feasible to assess individual aspects of the crime-vegetation association using methodologies suited to specific objectives. Stakeholder involvement should be a fundamental prerequisite underpinning such approaches. Further work is required to determine whether controlling IAPs in crime-ridden areas reduces the incidence of crime in these areas, or whether crime merely shifts to adjacent neighbourhoods. Indeed, allocating limited resources to clearing IAPs in crime-ridden areas solely to reduce levels of crime may not resolve safety and security issues in the long term, although other benefits to communities may emerge (e.g., improved perceived safety, increased provision of water and reduced fire risk). More work is needed to understand perceived personal safety in relation to vegetation. Moreover, alternative approaches to combatting crime require further examination such as the strategy of Crime Prevention through Environmental Design (Jeffery 1977).

CONCLUSIONS

This paper deliberates the notion that the structure of urban vegetation can influence the incidence of crime in urban areas. However, under certain circumstances (e.g., in Cape Town), the biogeographic provenance of plants is a determining factor in criminal behaviour. The extent to which alien plants are important in the context of vegetation as a mediator of crime depends largely on features of the native vegetation at a given site. Where the native vegetation is dense and resilient, the impact of invasions is likely to be small. However, where the native vegetation is short in stature and less resilient to major human-mediated disturbances (as in Cape Town), the contrast between native- and alien-dominated vegetation is much greater.

In Cape Town, stands of multiple alien and native plant species at different stages of invasion/densification

within a managed landscape can pose complex direct and indirect impacts that are likely to be overlooked by informal decision-making methods. Urban planners and managers face considerable challenges – they need to implement management strategies that restore and maintain biodiversity and ES provision, while also improving public safety. Reactive management approaches may persist as crime continues unabated and the association with vegetation becomes stronger as invasive plants continue to spread. A major challenge will be to identify and implement context-specific management approaches for vegetation (whether dominated by native, alien or invasive alien species) in urban areas to provide fewer opportunities for crime to occur.

The link between crime and vegetation structure, including that driven by plant invasions, is an important dimension of the “long and entangled history of humans and invasive introduced plants on South Africa’s Cape Peninsula” (Pooley 2018). This aspect has not been given the attention it deserves in integrated planning that aims to conserve the region’s unique biodiversity and to serve the needs of the growing urban population. While this phenomenon may be unique to Cape Town, further work is required in different contexts around the world to determine the role of urban vegetation in mediating criminal activity and whether similar management challenges exist.

Ethics approval and consent to participate

The study proposal was approved by the Research Ethics Committee of Stellenbosch University. Participation in interviews and surveys was voluntary; all participants were informed of their right to refuse to answer any questions and to withdraw from participation at any time. Informed consent was obtained, anonymity and confidentiality were explicitly granted, and questionnaires included no information that could be used to identify individual respondents. All data was thus anonymised prior to analysis.

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Supplementary Materials

Appendices S1-S3. Case Studies of vegetation-related crime in Cape Town, South Africa and questionnaire.

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