

**AUTHORS:**Sheunesu Ruwanza<sup>1</sup>   
Edward S. Mhlongo<sup>1</sup>**AFFILIATION:**<sup>1</sup>Centre of Excellence for Invasion Biology, Department of Environmental Science, Rhodes University, Makhanda, South Africa**CORRESPONDENCE TO:**

Sheunesu Ruwanza

**EMAIL:**

ruwanza@yahoo.com

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Salmina Mokgehele

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# *Lantana camara* invasion along road–river interchanges and roadsides in Soutpansberg, Vhembe Biosphere Reserve in South Africa

Roads and rivers act as conduits of alien plant invasion; however, little is known regarding the abundance and invasion extent of *Lantana camara*, an invasive shrub, along road–river interchanges and roadsides in South Africa. We assessed the effects of road–river interchanges and roadsides as invasion corridors that facilitate *L. camara* invasion. A road survey method was used to measure the invasion extent of *L. camara* along road–river interchanges and roadsides from national and regional roads covering 446 km in Soutpansberg, Vhembe Biosphere Reserve, South Africa. *L. camara* occurred along 21 of the 48 surveyed road–river interchanges and its abundance and cover were similar between road–river interchanges and roadsides, although height and diameter of *L. camara* were greater along road–river interchanges than roadsides. Other alien species that dominated road–river interchanges were *Solanum mauritianum*, *Caesalpinia decapetala* and *Rubus rigidus*. Our results indicate that *L. camara* dominates both road–river interchanges and roadsides, therefore roads and bridges should be considered important targets for *L. camara* control.

**Significance:**

- Despite the huge efforts by the South African government to control invasive alien plants, roads and rivers continue to act as important conduits for invasion and therefore there is a need to manage them.
- We propose that South African roads be considered important targets for efforts to control invasive alien plants.
- A policy and legislative framework around invasive alien plant removal during routine road maintenance operations is required.

## Introduction

Roads and bridges function as corridors for alien plant invasion and spread, although their importance has been neglected in managing invasive plants.<sup>1,2</sup> Rahlao et al.<sup>3</sup> highlighted that habitat disturbances at roadsides and road–river interchanges promote the establishment of invasive alien plants through the creation of suitable conditions for plant invasion through water and nutrient resource availability. Indeed, habitat fragmentation along roads and bridges enhances the establishment of disturbance-tolerant invasive plants, whilst withholding the establishment of local species.<sup>3,4</sup> Certainly, the colonisation of roadsides by invasive alien plants may act as a source for ensuing invasion into the neighbouring natural communities.<sup>3</sup> Few studies in South Africa have interrogated the effects of roadsides and road–river interchanges on invasion abundance and extent,<sup>3,4</sup> yet roads and rivers act as conduits for the efficient dispersal of alien plants. Against this background, we assessed the effects of road–river interchanges and roadsides as invasion corridors that facilitate *Lantana camara* invasion.

*Lantana camara* is an ornamental shrub which originates from South America. It has been declared a category 1b invasive plant in South Africa, meaning it must be controlled. It has invaded more than 2 million hectares in the country, and its negative impacts include a decrease in native species diversity, an increase in some soil physicochemical properties, and a reduction in grazing area.<sup>5–7</sup> Given the invasion status of *L. camara* in South Africa and the multiple functions of road–river interchanges and roadsides in facilitating alien plant invasion, we aimed to determine if the abundance and invasion of *L. camara* were higher under road–river interchanges than at roadsides. The study is motivated by the need to provide useful road and bridge management information.

## Methods and materials

The abundance and invasion extent of *L. camara* along road–river interchanges and roadsides were studied in Soutpansberg and its surroundings in the Vhembe Biosphere Reserve, Limpopo Province of South Africa (Figure 1a). The study area was selected due to the abundance of *L. camara* along roads and the dense national and regional road network. Vegetation in the study area is Soutpansberg Mountain Bushveld in the Soutpansberg mountain area, Makhado Sweet Bushveld and Musina Mopane Bushveld in the south and north of the mountains, respectively.<sup>8</sup> The average annual rainfall is between 340 mm and 1200 mm, being high in the mountainous area and decreasing moving away from the mountainous area. Most rain falls in summer between October and March and temperatures are hot in summer (averaging 40 °C) and mild in winter (averaging 4 °C).<sup>8</sup>

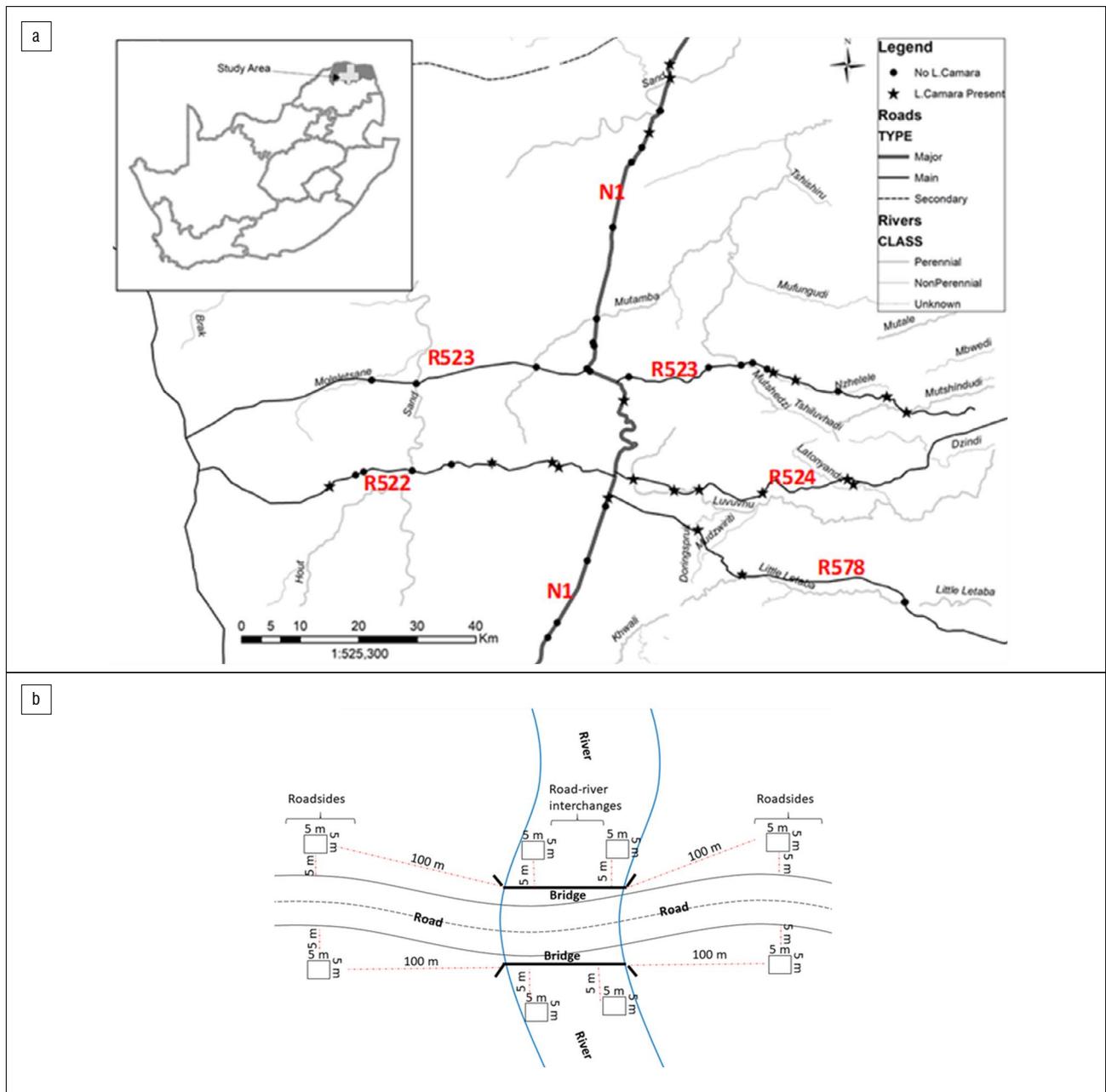
Using roadside surveys, a time and cost-effective method to detect invasive alien plants,<sup>4</sup> a total of 446 km (totalling 48 road–river interchanges) was surveyed along five major roads in the study area. The surveyed roads were: (1) National Road 1 (N1) from Capricorn Tollgate to Musina (143 km), (2) Regional Road 524 (R524) from Makhado (previously known as Louis Trichardt) to Thohoyandou (70 km), (3) Regional Road 523 (R523) from Thohoyandou to Vivo (140 km), (4) Regional Road 578 (R578) from Makhado to Elim (23 km), and (5) Regional Road 522 (R522) from Vivo to Makhado (70 km). Surveys were conducted in winter in July and August 2018 when most road–river interchanges were dry. At each road–river interchange, four plots (two on both sides of the bridge),

each measuring 5 x 5 m, were set up on the riparian zone (approximately 5 m from the bridge wall). These four plots were referred to as road–river interchanges plots. An additional four plots, with similar dimensions, were set up 100 m from the bridge along the road (approximately 5 m from the road) and these were referred to as roadside plots (Figure 1b).

On every road–river interchange where *L. camara* was present, a detailed vegetation survey was conducted in all road–river interchange and roadside plots, resulting in 168 plots being surveyed (8 plots x 21 road–river interchange). Within each plot, species richness and density of all the trees and shrubs were determined from counts of individual plants per plot. In addition, height of all identified individual plants was measured using a ranging pole with 10-cm graduations. Diameter at base for each plant was measured using a Vernier caliper (for multi-stemmed plants only the largest stem was measured). Plant cover was visually estimated as a percentage per plot. All trees and shrubs were

collected for identification at the University of Venda herbarium in the Department of Botany.

A *t*-test was performed in Statistica version 13.2 to assess differences between road locations on measured variables. Species richness, Shannon–Wiener diversity index ( $H'$ ) and evenness index ( $J$ ) were calculated per plot and used to examine species diversity between road location. Data were tested for normality and proof of homogeneity of variances using Kolmogorov–Smirnov and Levene tests, respectively, and data were normally distributed. Species occupancy frequencies (expressed as a percentage) were calculated as the number of times a plant species is present in the different plots. Using the presence and absence data, principal component analysis (PCA) was performed to investigate how plots and species change species composition. PCA was performed using Canoco for Windows version 5.



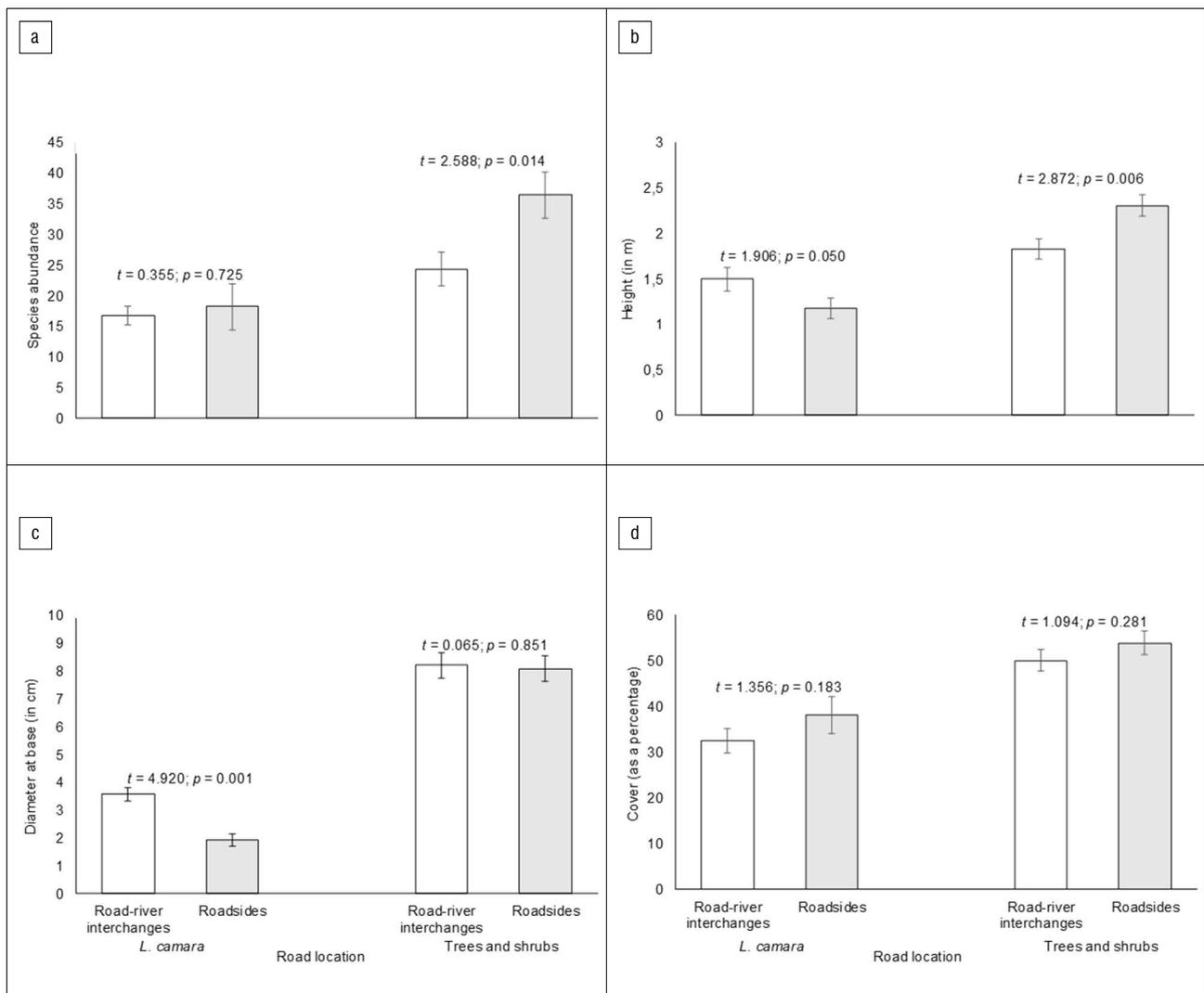
**Figure 1:** (a) Location of the study area in Vhembe Biosphere Reserve, Limpopo Province of South Africa with surveyed national and regional roads shown. (b) Schematic illustration showing how plots were sampled at different road locations.

## Results

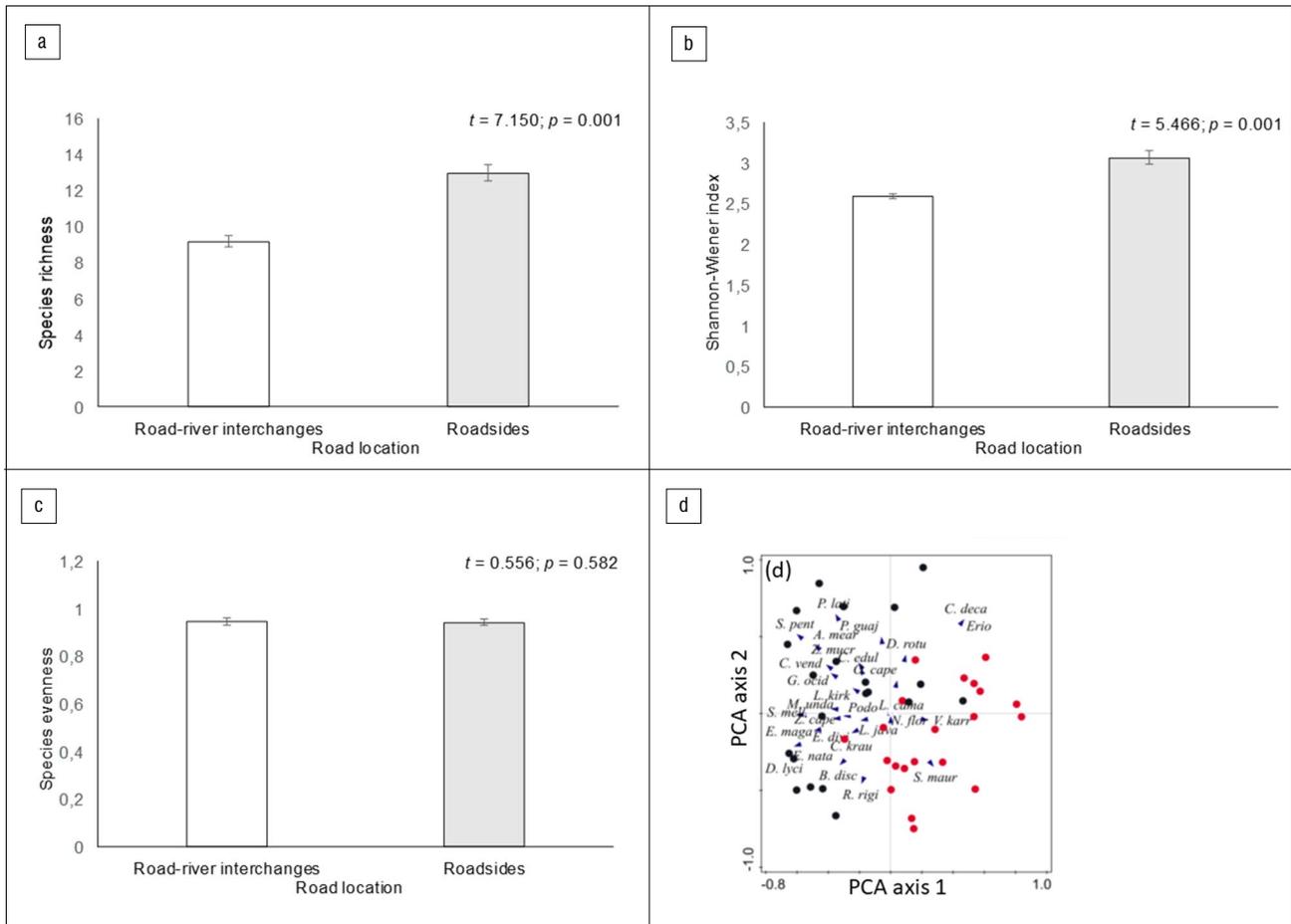
Of the 48 road–river interchanges surveyed, 21 (44%) had *L. camara* along both road–river interchanges and roadsides. A total of 1118 *L. camara* individuals were recorded, of which 352 were along road–river interchanges and 766 were along roadsides. Average *L. camara* abundance per plot showed no significant ( $t=0.355$ ;  $p=0.725$ ) differences between road–river interchanges and roadsides (Figure 2a). In contrast, the abundance of other trees and shrubs was significantly ( $t=2.588$ ;  $p=0.014$ ) higher along roadsides than road–river interchanges (Figure 2a). Height of *L. camara* was significantly ( $t=1.906$ ;  $p=0.05$ ) higher along road–river interchanges than roadsides, whereas height of other trees and shrubs was significantly ( $t=2.872$ ;  $p=0.006$ ) higher along roadsides than road–river interchanges (Figure 2b). Diameter at base of *L. camara* was significantly ( $t=4.920$ ;  $p=0.001$ ) higher along road–river interchanges than roadsides. However, diameter at base of other trees and shrubs showed no significant ( $t=0.065$ ;  $p=0.851$ ) differences between road–river interchanges and roadsides (Figure 2c). Cover of both *L. camara* and other trees and shrubs showed no significant ( $p>0.05$ ) differences between road–river interchanges and roadsides (Figure 2d).

Both species richness and Shannon–Wiener showed significant ( $p=0.001$ ) differences between road–river interchanges and roadsides (Figures 3a and b). The above-mentioned differences in species

richness and Shannon–Wiener showed greater diversity along roadsides than road–river interchanges (Figure 3a and 3b). However, there were no significant ( $p=0.582$ ) differences in species evenness between road–river interchanges and roadsides (Figure 3c). A total of 29 trees and shrub species were recorded in all plots (Supplementary table 1). Besides *L. camara* dominating road–river interchanges, other species with more than 60% occupancy frequency were the alien species *Solanum mauritianum*, *Caesalpinia decapetala* and *Rubus rigidus* and the native species *Diospyros lycioides*, *Euclea natalensis*, *Lippia javanica*, *Podocarpus* sp. and *Vachellia karroo* (Supplementary table 1). Similarly, *L. camara* dominated roadsides, and other species with occupancy frequency greater than 80% were the alien species *Acacia mearnsii* and native species *D. lycioides*, *E. natalensis*, *L. javanica*, *Podocarpus* sp., *Searsia pentheri* and *V. karroo* (Supplementary material 1). Five native species, namely *Combretum vendae*, *Englerophytum magalismontanum*, *E. divinorum*, *P. latifolius* and *Zanthoxylum capense* were not present along road–river interchanges but appeared along roadsides with an occupancy frequency of less than 60%. PCA showed little separated road–river interchanges and roadsides in ordination space determined by the first two axes between them (Figure 3d). Nevertheless, clear distinctions can be seen regarding assemblages for some species, for example, *S. pentheri*, *P. latifolius* and *Psidium guajava* assembled more along roadsides than did *S. mauritianum*, which assembled more along road–river interchanges (Figure 3d).



**Figure 2:** Comparison of (a) species abundance, (b) height, (c) diameter at base and (d) cover for *L. camara* and other trees and shrubs at different road locations. Data are means  $\pm$  s.e. and *t*-test results are shown.



**Figure 3:** Comparison of (a) species richness, (b) Shannon–Wiener index and (c) evenness at different road locations. Data are means ± s.e. and *t*-test results are shown. (d) Principal component analysis (PCA) of species (▲) and road location as (●) road–river interchanges and (●) roadsides for identified trees and shrubs. The first four letters of the species names are presented, with full names given in Supplementary table 1.

## Discussion

In this study, *L. camara* abundance and cover were similar between road–river interchanges and roadsides. Height and diameter of *L. camara* were greater along road–river interchanges than roadsides – an indication that the species grows better at road–river interchanges than roadsides. Therefore, it is evident that road–river interchanges facilitate *L. camara* invasion and create suitable conditions for the species to establish. This result concurs with previous studies on other invasive species, e.g. *Pennisetum setaceum* which dominates South African roadsides but grows better under road–river interchanges.<sup>3</sup> Similarly, Beard and Kraaij<sup>4</sup> identified 109 invasive plant species along the Garden Route roads, with the highest incidences being on degraded and transformed lands as well as farm roads. Other studies also reported that invasive plants such as *Clidemia hirta* dominate roads and trails in Malaysia<sup>9</sup>, whilst *Ambrosia artemisiifolia* dominate paved roads in Canada<sup>10</sup>. We suspect that both road–river interchanges and roadsides contribute to invasion by invasive alien plants through (1) provision of migration corridors, (2) creation of microcosm environments (especially road–river interchanges) that are suitable for invasive plant growth and establishment, and (3) road construction and maintenance disturbance which create conditions for alien plant establishment through soil movement.<sup>1,3,11,12</sup> In addition, several environmental factors (e.g. soil type, flooding and climate change) can influence the abundance and spread of invasive plants along road–river interchanges and roadsides.<sup>3</sup> Given the fact that other invasive plants like *S. mauritanum*, *C. decapetala*, *A. mearnsii* and *R. rigidus* were present at surveyed road locations, our observations are consistent with the suggestion that road–river interchanges and roadsides facilitate invasion by invasive alien plants.<sup>3,12</sup> Beard and Kraaij<sup>4</sup> identified 35 sleeper weeds

that displayed invasion plant tendencies but are not listed by the South African Plant Invader Atlas or regulated by legislation. In this study, the occurrence of other woody invaders on surveyed plots seems to suggest that road–river interchanges and roadsides, like any other disturbance mechanism, promotes co-occurrence of invaders.

Although roadside surveys have disadvantages – e.g. poor detection of plants far from the road verge and a bias towards large growth form – results of this study suggest that the abundance and invasion of *L. camara* is concentrated along both road–river interchanges and roadsides, an indication that roads and bridges play a key role in facilitating *L. camara* invasion and establishment. The presence of *L. camara* along road–river interchanges and roadsides poses a major problem as the plant can produce more propagules that might be dispersed along the road and river, resulting in *L. camara* expansion. Because roads and bridges are important within the national infrastructure, proper management of *L. camara* and other invasives along roads and bridges is required. We recommend that road–river interchanges and roadsides be prioritised during invasive alien plant control in South Africa.

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## Competing interests

We declare that there are no competing interests.

## Authors' contributions

E.S.M.: Collected the data and drafted the manuscript.  
S.R.: Conceptualised the study, methodology, funding acquisition, verified the data set used in the final analysis, participated in the revision of the manuscript, student supervision, and project leadership and management.

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