APPLICATION OF GIS AS A TOOL FOR MONITORING *Lantana camara & Chromolaena odorata* IN HURULU BIOSPHERE RESERVE IN SRI LANKA USING INVERSE DISTANCE WEIGHTED METHOD

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Summary

*Human-elephant conflict is one of the worst environmental and rural social problems in Sri Lanka especially in the dry zone. Due to various reasons, approximately 60%-70% of Sri Lankan's wild elephants (*Elephas maximus maximus*) live outside the protected areas. Invasive alien flora species such as* Lantana camara *(Lantana /Gandapāna) and* Chromolaena odorata (Eupatorium odoratum) *(Podisngho Maran) are the most problematic in the protected areas of Sri Lanka and they could potentially reduce the quantity of forage available for wild elephant. As a result, wild elephants roam in to peripheral villages of protected areas and that could increase the level of human-elephant conflict. The aim of the study was to generate the predicted maps instrumental in the monitoring of above mentioned invasive species which are the most threatening in the Hurulu International Biosphere Reserve that is situated in North-central Province of Sri Lanka. This reserve is a popular tourist destination among wildlife enthusiasts owing of its greenery and wild life especially elephants. Systemic sampling design with a total of 132 sampling sites were located on the ground using a GPS unit along the both sides of road track to obtain the spreading density of two invasive species. Nearest neighbour interpolation technique, Inverse Distance Weighting (IDW) of ArcView GIS 3.2 was used to synthesis predicted maps. Results revealed that* Lantana camara *has infested the area more than* Chromolaena odorata. *Also, lantana spreads moderately at some areas as small patches mainly along the edges of the roads. In comparison to other protected areas in Sri Lanka, there are no severe threats from these two invasive alien species. But generated maps are particularly useful to manage Hurulu Forest Reserve for monitoring the spread of invasive species and conducting associated early response actions to control them efficiently and effectively.*

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INTRODUCTION

Invasive alien species (IAS), climate change, with the land use change and changes in the nitrogen and carbon cycles are identified as the main four drivers of global biodiversity loss while IAS are considered as a second major threat to biodiversity (Masters and Norgrove 2010). Hence, IAS is causing major impacts on biodiversity at global level and it has been estimated that at least 39% of species extinctions during the past 400 years are as a consequence of these species (www. indiaenvironmentportal. org.in/node/38152). According to the Millennium Ecosystem Assessment, IAS is not only affecting biodiversity but also water, soil and scenic beauty of protected areas. Due to this biological invasion, gene pool, species, ecosystems and its service across the world as well as human development, human health and livelihood have been disturbed seriously (Millennium Ecosystem Assessment 2005).

The most of the protected areas, set aside to maintain proper functioning of natural ecosystems, to act as refugees for species and to maintain ecological processes (Dudley, 2008) have been threatened by invasive alien species. Hurulu Forest Reserve is situated in the dry zone, which is the one of four International Biospheres Reserves (IBR) designated under UNESCO in Sri Lanka. Due to riverine forests, flat lands, abundance of grasslands (*Panicum maximum & Imperata cylindrica)* and minimal human intervention level, Hurulu Reserve is famous as an elephant habitat.

Since it was opened for outdoor recreation in 2007 by the Forest department, gradual spread of gandapana *(Lantana camara) &* podisinghomaran (*Chromolaena odorata)*, which are considered as forest invasive species are being observed along the roadsides as small dense patches. Lantana is a major invasive flora species, which can significantly reduce the grazing fields of elephant (Marambe 2003). In term of economics, controlling of forest invasive species is not cost effective when they are colonized in natural and semi-natural habitats. Dense spread of both of these forest invasive species often dislodge native vegetation, exposing bare soil and increasing the erosion. Moreover, they also overtop the indigenous vegetation, depriving the plants of sunlight and thus causing them to decline. This reduction of indigenous vegetation, in turn, renders changes in associated plant and animal life.

Likewise, elephant damage in young teak plantations in Hururlu reserve and increased pressure of elephant attacks on peripheral villages are caused by reduction of fodder.

However, an on-going monitoring program is an essential element in habitat management of Hurulu to eradicate IAS before it spreads widely. Predicting the ecological behaviour of a species in a new environment may be impossible (Williamson 1999). The consequence of a given disturbance depends on the properties of the ecosystem or species.

To manage and control IAS effectively in protected area, and to protect and preserve local biodiversity and ecosystem functioning, park warden requires an accurate and timely spatial information to delineate the location, spatial extent, and intensity of the invasion (Lawrence *et* al. 2005). Spatial information about IAS assists park warden of Hurulu forest in monitoring the efficacy of current management and control strategies and possible future invasions (risk assessment), and assists in identifying target species and areas for clearing (Poona 2004). Therefore, application of GIS for mapping of spatial distribution of IAS may allow protected area manager to predict patterns of invading species more successfully.

This study aims to quantify the spreading density and mapping the spatial distribution of two problematic invasive plant species, mainly along the roadsides of Hurulu Forest Reserve.

METHODOLOGY

Study Sites

Hurulu Forest Reserve (HFR), which covers an area of 25,217 hectares spreading over Polonnaruwa (18,268 ha) and Anuradhapura (6,948ha) Districts in Sri Lanka, was gazetted as a National Forest Reserve in 1942 (Weerakoon et al. 2010). Further, it was upgraded to an International Biosphere Reserve in 1977 (Forest Department 2011). In addition, Hurulu was declared as a Conservation Forest in 2012. It is in the North-central Province of Sri Lanka located in between the latitudes 8° 122'to 8°21' N and longitudes 80° 50' and 80° 84'E (Wikipedia.org 2012).

Moreover, it is situated in the dry zone area and, a dry monsoon type climate prevails with mean annual precipitation of 1,600 mm and a mean annual temperature of 27-30°C (UNESCO 2009). It consists of tropical dry forest (Miles et al. 2006), with a typically layered structure comprising an upper canopy of moderately large trees, a sub canopy of smaller pole-sized species and a distinct herb layer (Forest Department 2011). In addition, small patch of various forest types such as riverine forests, sparse and open forests and forest plantation of teak (*Tectona grandis*), khaya (*Khaya senagalensis*), and eucalypts (*Eucalyptus camaldulensis)* are scattered in some parts of the reserve. In term of species diversity, satinwood (*Chloroxylon swietenia*), palu (*Manilkara hexandra*) and ebony (*Diospyros ebenum*) (Forest Department 2011) are dominant flora species in Hurulu Reserve while tortoise (*Testudo elegans*), Ceylon junglefowl (*Gallus lafayettii*), asian elephant (*Elephas maximus maximus*), leopard (*Panthera pardus*) and the rusty-spotted cat (*Felis rubiginosa*) (UNESCO 2009) are dominant faunal species.

A stretch of 1000 ha land in the Hurulu Forest Reserve belongs to Hingurakgoda Divisional Secretariat area that was declared and opened as an eco-park in 2007 by the Forest Department and it has been used in the present study as illustrated in Plate 1.

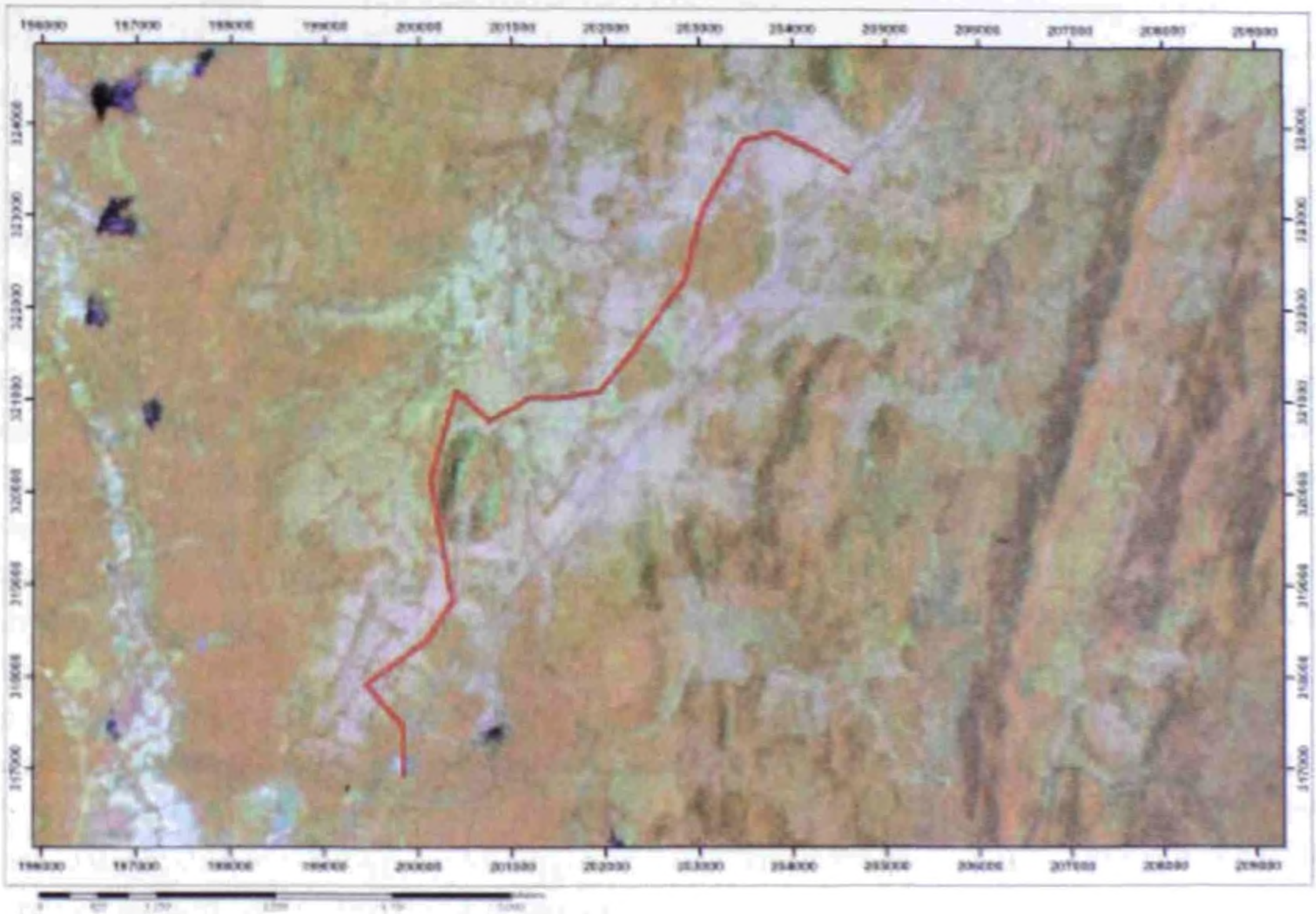

Plate 1: Google image of research area displaying the road track

Data Collection and Analysis

The vegetation survey was based on systematic sampling design with a total of 132 sampling points. 4 x 4 m quadrat was used to sample density of *Lantana camara* and *Chromolaena odorata.* Numbers of bushes of both IAS were counted in each sample point. Sampling points were located by using a GPS at 500m interval on both sides of 11 km length road tract which was newly opened for observing wild elephant.

In each side, samples were laid out at 0m, 40m, and 80m distance from edge of the road at perpendicular directions as in figure 1. Ms Access was used to prepare the database to store data, which were obtained during the study. Environmental System Research Institute's (ESRI) Arc View GIS 3.2 software was used for analysis. Furthermore, Inverse Distance Weighted (IDW) interpolation-modelling technique was used to generate a predicted map of distribution of the selected species.

Inverse Distance Weighted (IDW) interpolation modelling is a potential time saving alternative to current survey methods for generating invasive plant distribution maps (Roberts et al. 2004). Some studies showed that Kring interpolation is more robust and desirable. However, under conditions of high spatial autocorrelation, comparison studies revealed that IDW is equal to and at times more successful than Kring (Bowman et al. 1995; Gotway et al. 1996; Dirks et al. 1998). Hence, due to the simplicity, easiness in use and high accessibility, IDW method was used for this study instead of Kring. Same as other methods, IDW uses linear combinations of weights to get the points to estimate unknown location values.

Based on power value, it can control the significance of surrounding points on the interpolated value. By defining a higher power, more emphasis is placed on the nearest points, and the resulting surface will have more details (be less smooth). Specifying a lower power will give more influence to the points that are farther away, resulting in a smoother surface. It can be any real number greater than zero, but the most reasonable results will be obtained using values from 0.5 to 3. However, a power of two is the most commonly used with IDW and it , also , is the default value. (Watson and Philip, 1985). Hence, a power of two was applied for the present study.

RESULTS AND DISCUSSION

The highest density of *Lantana camara* (2.18 bushes/m^2) was recorded right hand side of the road adjacent to about 4000m-4500m from the starting point of the road which is situated near the main building complex in Hurulu Eco- park, followed by 1.92 bushes/m^2 about 7000m-7500m on the left hand side of the road as illustrated in figure 2. In addition, spreading densities of Lantana, 1.56 bushes/ m^2 and 1.37 bushes/ m^2 at between 6000m-7500mm were recorded on the left hand side of the road towards the forest at 40m and 80m distances respectively.(figure 3)

Chromolaena odorata showed lower densities than *Lantana camara* with the peak around 1.37 bushes/ m^2 at 8000m-8500m on the left hand side from the starting point of the road.

Overall, results revealed that in the predicted maps of *Lantana camara & Chromolaena odorata,* less spreading density was shown in the most of the areas as illustrated in figures 4 and 5. Somehow, high spreading densities were predicted between 3.5km and 5km as well as 7km and 8km from the entrance of Hurulu Forest Reserve. However, spreading density of *Lanatana* towards the forest area from each side of road was diminishing gradually. Moreover, impacts of *Chromolaena odorata* on both side of the road are very low as in figure 5.

In this study, Inverse Distance Weighted (IDW) interpolation modelling was used as a potential time saving alternative to current survey methods for generating invasive plant distribution maps for Hurulu Eco-park. For applying IDW method to generate prediction maps, systematic sampling is the most appropriate sample method (Roberts et al. 2004). However it has some limitation such as variations

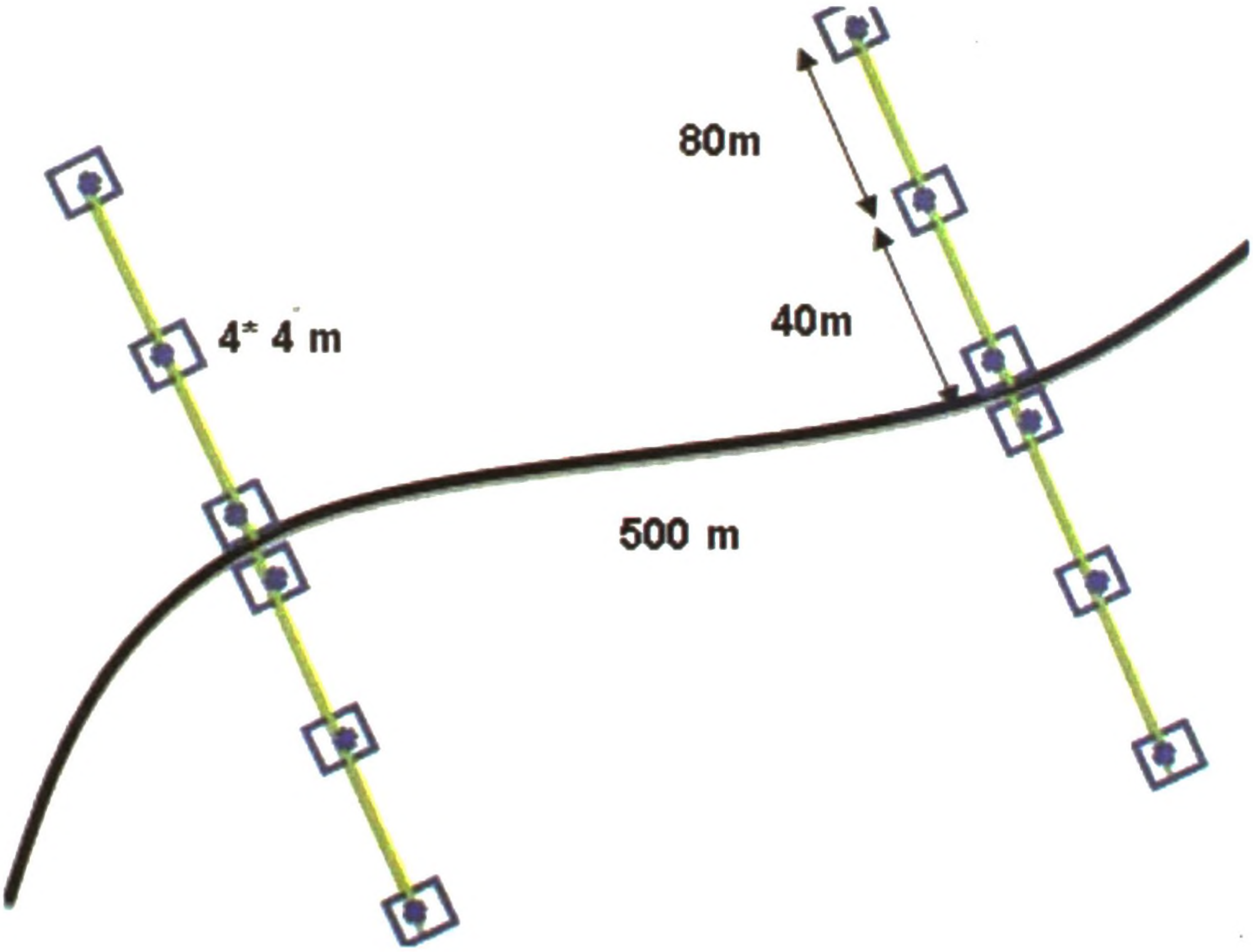

Figure 1: Layout of data collection points in Hurulu Forest Reserve.

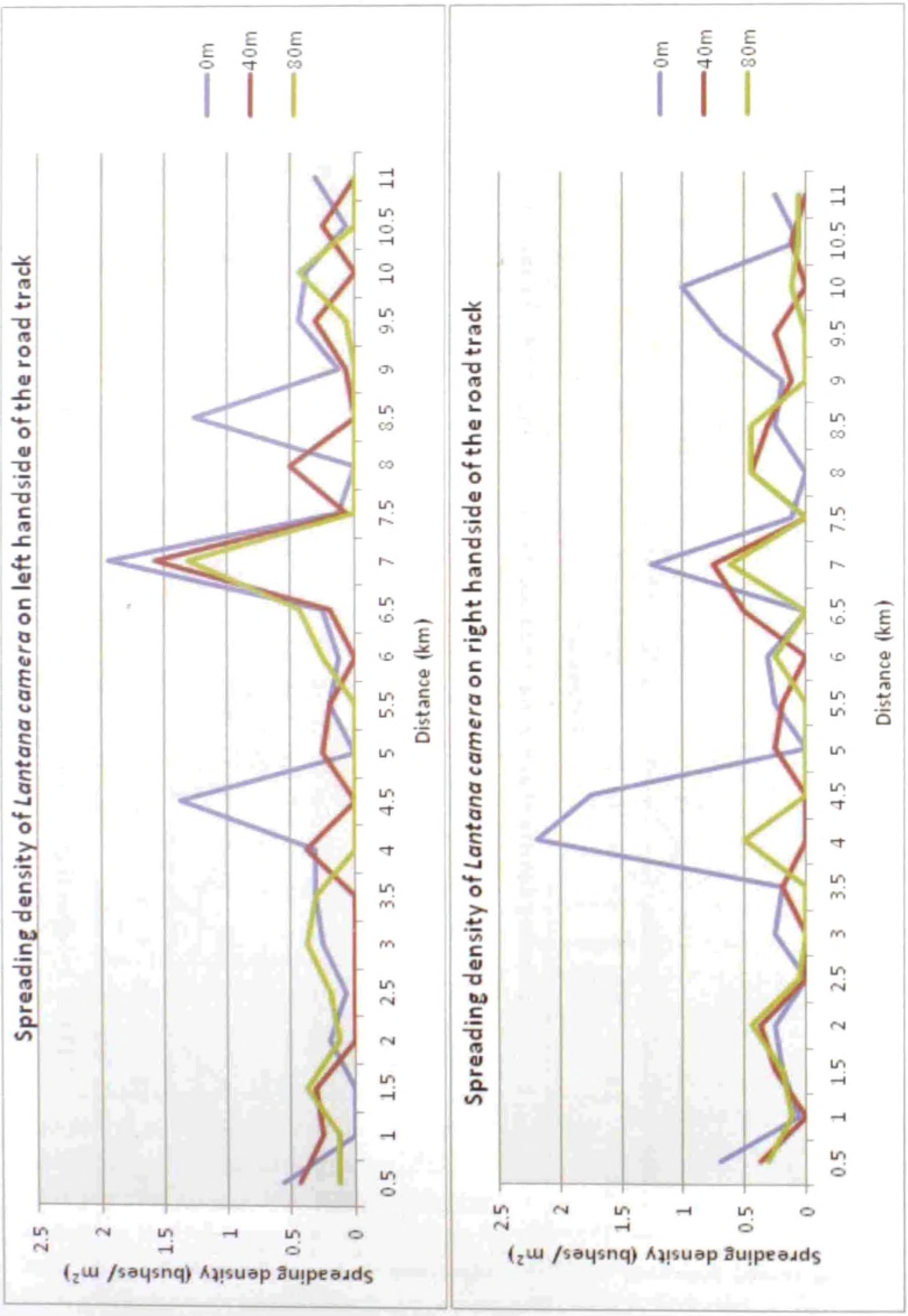

Figure 2: Spreading density of *Lantana camara* (Right & Left hand side, 0m, 40m and 80m from the road track)

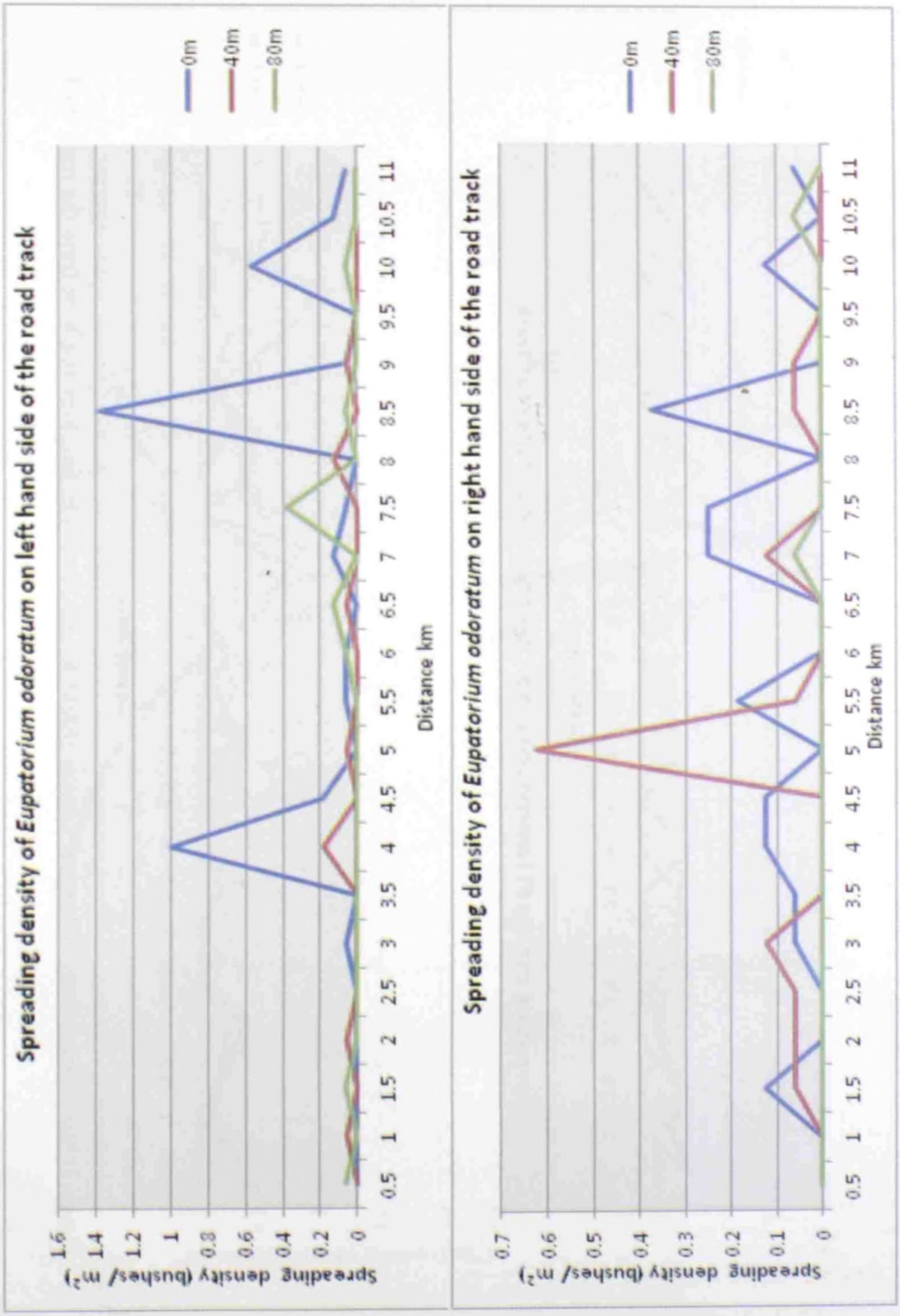

Figure 3: Spreading density of *Chromolaena odorata (Eupatorium odoratum)*

(Right & Left hand side, 0m , 40m and 80m from the road tracks.

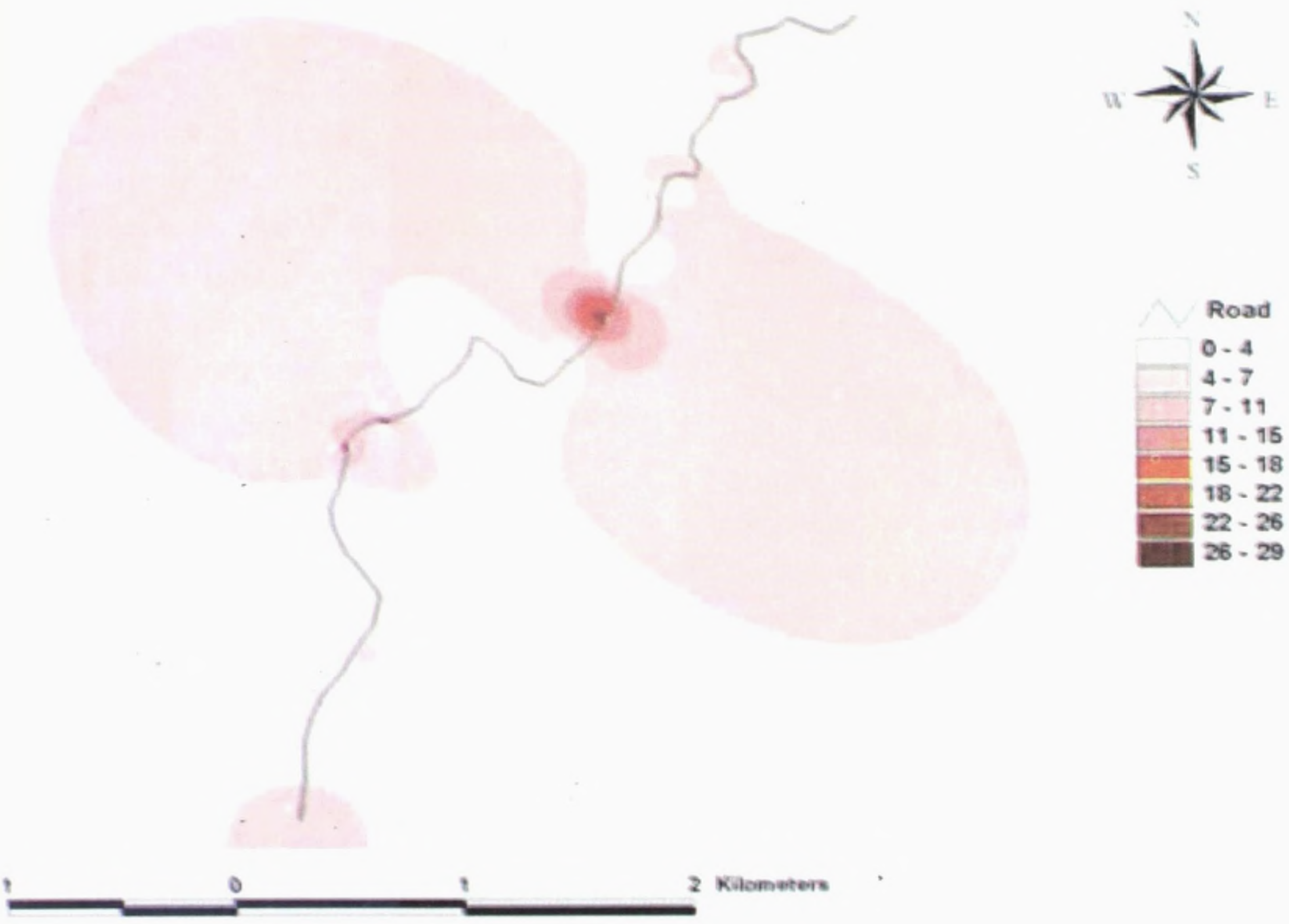

Figure 4: Spatial distribution and abundance of *Lantana camara* along both sides of elephant observation path in Hurulu Forest Reserve.

in systematic sample locations can, at times, result in non-representative samples (Podani 1984), and if the sampling interval is not synchronized with the plant distribution, interpolation success may decrease.

Furthermore, invasiveness of IAS of Hurulu Eco-park is not well documented. In addition, experiences of eradication campaigns of IAS in other protected areas showed that the failure of eradicating the IAS especially *Lantana* when it becomes the menace. Hence, these prediction maps give some basic insight to park authorities of Hurulu Eco-park for monitoring changes of existing IAS and to prevent IAS from becoming a menace. Also, this indicates area which should be given priority in controlling IAS.

CONCLUSION & RECOMMENDATION

According to the result, *Lantana camara* has spread along the road track in Hurulu Forest Reserve more than *Chromolaena odorata* . Highest numbers of spreading densities of both species were recorded at the edge of the road

Figure 5: Spatial distribution and abundance of *Chromolaena odorata* along the both sides of elephant observation path in Hurulu Forest Reserve.

track. Also, spreading densities have been reduced towards the forest. In addition, predicted maps suggested that possibility of moderate to severe infestation of *Lantana camera* on both side of the middle part of the road track. However, *Chromolaena odorata* showed very less infestation.

Nevertheless, periodic mapping is essential for evaluation and adaptive management to prevent heavy infestation risks of *Lantana,* which reduce both quantity and quality of forage available to asian elephant, decrease the conservation value and increase the fire hazard in Hurulu Biosphere Reserve. In addition, continuous monitoring is useful to prevent *Lantana camara & Chromolaena odorata from* becoming serious invaders of Hurulu Forest Reserve.

Maps of spatial distribution of both species help to predict the condition of habitat in a larger area using a small number of sample points with accurate evaluation. It facilitates the park management to reduce time and labour cost. Reliable prediction maps of the abundance of the invasive species over the landscape are an invaluable conservation monitoring and planning tool for the management of Hurulu Forest Reserve for multiple objectives in term of ecological and economic aspects. Overall, these maps can be used as a sound decision-making tool for the management of habitats as well as for the conservation of biodiversity.

ACKNOWLEDGEMENTS

Authors specially thank to Range Forest Officer, Habarana and his field staff for excellent fieldwork amidst the threats of heavy wild elephant attacks. We also thank Mr. Atapattu, Park Warden and other staff attached to Hurulu Eco-park, who helped in many ways, especially in conducting field surveys.

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