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INFLUENCE OF URBAN DISTURBANCES, SOIL PROPERTIES, AND OTHER ABIOTIC AND BIOTIC FACTORS ON L. MAACKII INVASIONS OF REMNANT URBAN RIPARIAN HARDWOOD FORESTS

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L. MAACKII INVASIONS OF REMNANT URBAN RIPARIAN HARDWOOD FORESTS

by

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ABSTRACT

Urbanization is a global demographic trend that may have significant and detrimental effects on adjacent urban ecosystems. *Lonicer Maackii (L. maackii)*, commonly referred to as Amur honeysuckle, is an invasive shrub that has invaded the remnant temperate hardwood forests of Rock Island County, IL. The goal of this study was to examine the effects of urbanization and urban soil properties on the degree of *L. maackii* invasion throughout this county next to the Mississippi river. Soil samples were tested at 36 forest sites for Soil Organic Matter and Soil texture. Linear regression models were ran on the results of these tests between *L. maackii* cover and other abiotic and biotic site variables. The results of this study indicate that there is no single driver of *L. maackii* invasion. However, specific soil properties and abiotic and biotic site variables may increase the likelihood of *L. maackii* establishment and dominance. Multiple properties and variables attributed to *L. maackii* cover identified in this study include % forest cover, % green and other open space, garbage levels, % impervious surface, % total urban canopy cover, total invasive cover, % clay soil texture, forest floor litter levels, and % slope. The identified properties and variables that may increase *L. maackii* establishment and dominance are associated with urban-related disturbances. Understanding the interaction between urban-related disturbances and *L. maackii* cover may allow for better land use planning and city management in the future.

INTRODUCTION

Urban centers currently contain over 50% of the global population with rising projections estimating that 80% of the US population will live in urban areas within the next 25 years (Pickett et al. 2011). Urban riparian forests provide a multitude of ecosystem functions, acting as buffer zones slowing the movement of run-off across the urban landscape (White et al. 2014). Slowing run-off across the urban landscapes helps to preserve key aspects of the hydrologic cycle by capturing, storing, and safely releasing stormwater; thereby performing an ecosystem service of hydrologic filtration and thus, lowering the amount of nutrients and other pollutants reaching urban streams (Pennington et al. 2010). Urban riparian areas can also preserve biodiversity by serving as refuge corridors for floral and faunal species, helping to lessen the negative impacts of habitat fragmentation and degradation caused by urban disturbances (Dallimer et al. 2012). Urban riparian forests also preserve connectivity among remnant habitat patches and thereby enhance native species' mobility by enhancing seed germination, seed dispersal, and species migration (Pennington et al. 2010). This enhanced connectivity can reduce the adverse impacts associated with novel stresses created by urban environments (Pennington et al. 2010). Better understanding urban forest riparian ecosystems and their functions will continue to increase in importance for future urban forest management and city planning efforts to ensure long-term sustainability of these important ecosystems.

Urban-related alterations of forest composition and structure of remnant in urban forests can be indicative of larger-scale spatial and regional ecosystem shifts (White et al. 2014). Disturbances associated with urbanization, such as impervious surface (roads, buildings, parking lots) can significantly increase the magnitude of exotic invasions (Daehler et al. 2003). Native herbaceous species abundance in urban riparian canopies and understories is lowered with greater fragmentation associated with the amount of impervious surface located within 250m of effected sites (Pennington et al. 2010; Cameron et al. 2015). Further, impervious surfaces influence urban forests, urban soils, and results in a greater abundance of non-native herbaceous species as well. (Cameron et al. 2015). Further, urbanization may lower the native tree and herbaceous understory diversity in remnant forests (Cameron et al. 2015). Finally, urbanization dramatically increases fire suppression efforts to protect human life and property (Nowacki et al. 2008).

Prior to European settlement in North America, open-canopy oak-hickory dominated forest, oak savannahs, and tallgrass prairie dominated substantial areas of the Midwest region of the US as a result of fire regimes consisting of high frequency but low severity fires (Nowacki et al. 2008; Pennington et al. 2010). Altering natural disturbance regimes can result in regional shifts in ecosystem composition, structure, and services. This fire regime drove ecosystem functions throughout the region and resulted in ecosystems dominated by xeric, heliophytic, shade-intolerant, and fire tolerant herbaceous species (Nowacki et al. 2008). Since European settlement, fire suppression throughout the region has driven the conversion of xeric-dominated ecosystems to mesic-dominated ecosystems, where shade-tolerant, fast-growing, competitive species, such as maple and elm species, dominate (Nowacki et al. 2008). This process of mesophication is altering the composition and structure of Midwestern forests, and such changes are predicted to occur faster and be more severe on more productive sites where mesic species can take advantage of increased resource availability (Nowacki et al. 2008; Daehler 2003).

Alterations of natural disturbance regimes can increase the establishment and dominance of invasives by increasing resource availability (light, nutrients, water, etc.) (Daehler 2003). Many invasive species have high resource uptake and growth rates and can quickly outcompete slower growing native species (Dallimer et al. 2012). Because urban riparian forests are more susceptible to exotic invasion (Sung et al. 2011; Borgmann et al. 2005), mesophication may be accelerated in areas throughout the

Midwest where urbanization and habitat fragmentation is occurring. However, we have a poor understanding of how the process of mesophication and urban-related disturbances interact to influence the magnitude of invasion in remnant urban forests.

Lonicera maackii (L. maackii), commonly known as Amur honeysuckle, is an invasive shrub that has quickly invaded temperate, hardwood deciduous forests of the United States (Cameron et al. 2015). *L. maackii* invasions have been especially rapid and severe in urban areas characterized by habitat fragmentation and disturbance (Pipal 2014), and *L. maackii* often dominates remnant forest understories along forest edges where ecosystem types abruptly shift (Trammell et al. 2012; Gorchov et al. 2014). Multiple studies indicate that *L. maackii* may significantly alter the lower forest canopy but that the direct effects may be difficult to measure in forests where *L. maackii* is abundant (Borgmann et al. 2005; Pipal 2014; White et al. 2014; Cameron et al. 2015). Further, previous studies indicate that there is not a significant relationship between *L. maackii* abundance and native abundance and diversity, particularly in areas where invasion of *L. maackii* was widespread (Borgmann et al. 2005; Cameron et al. 2015). Changes in the native plant community and forest understory composition may influence microclimate factors (Trammell et al. 2012).

Soils under *L. maackii* receive less moisture because the occurrence of *L. maackii* increases the evapotranspiration surfaces of the forest understory (Pipal 2014; McEwan et al. 2012). Further, soils under *L. maackii* receive less precipitation because *L. maackii* tends to establish as dense monocultures, contributing to less precipitation reaching the forest floor (Pipal 2014). *L. maackii's* leaves bud earlier and persist longer than most surrounding native herbaceous species, creating more shade for a more prolonged period of time. These changes can give an advantage to other invasive species over native species (Daehler 2003). *L. maackii* can also alter the amount of leaf litter on the forest floor (Pipal 2014). Forest sites with greater *L. maackii* densities have faster leaf litter decomposition rates since *L. maackii* leaf litter decomposes faster than most natives and may even accelerate native leaf litter decay rates

(Pipal 2014; Trammell et al. 2012). Faster decomposition rates of leaf litter results in less overall litter on the forest floor at any given time (Pipal 2014). Reduced litter levels may translate into a lack of fine fuels necessary to carry prescribed burns, a frequently used restoration tool in these ecosystems (Nowacki et al. 2008). The relationship between *L. maackii*, soil properties, and other biotic and environmental factors remain poorly understood.

Soil properties and other environmental factors can influence the composition and structure of forest ecosystems (Pickett et al. 2011). Soils provide important ecosystem services including biogeochemical and hydrologic cycling (Pickett et al. 2011). Anthropogenic and physical disturbances can alter soil characteristics and ecosystem services, including altering the soil's parent material and enhanced erosion and deposition rates (Pickett et al. 2011). Soil characteristics such as parent material, texture, and microclimate directly effect and alter pedogenic processes (Schaetzl et al. 2005). Soil moisture, a microclimate factor, in urban soils may be greater in soil horizons nearer the surface because of reduced water infiltration associated with sudden changes in soil texture and structure caused by compaction and other urban disturbances (Pickett et al. 2011).

The objective of my study was to examine *L. maackii* invasion in urban riparian forests undergoing rapid mesophication in Rock Island County, IL. I aimed to answer the following research questions:

1. What is the relationship between soil properties and the magnitude of *L. maackii* invasion?
2. How do soil properties and the interaction with other biotic and abiotic ecosystem variables relate to *L. maackii* invasion?

LITERATURE REVIEW

Fire suppression in the Midwest has led to significant regional shifts in temperate hardwood forest composition and structure. Prior to European settlement in North America, open-canopy oak-hickory dominated forest, oak savannah, and tallgrass prairie dominated substantial areas of the Midwest region of the US as a result of fire regimes consisting of high frequency but low severity fires (Nowacki et al. 2008; Pennington et al. 2010). Midwestern fire regimes were maintained by Native Americans and their frequent burning made them a keynote species in these ecosystems (Nowacki et al. 2008). Areas in the Midwest that have not been converted to agriculture have shifted from oak-hickory dominated (heliophytic species), open-canopy forests to closed-canopy forests dominated by maple, basswood and other mesophytic tree species (Nowacki et al. 2008).

Fire regimes in the Midwest have served as evolutionary drivers to native herbaceous species. They adapted to live in fire-abundant environments that thrive under fire regimes (Nowacki et al. 2008). Fire regimes are open-canopy systems. Thus, many plants in the region evolved to be heliophytic, favoring areas of high light availability and avoiding areas of low light availability (Nowacki et al. 2008). Fire suppression-driven dominance of shade tolerant, mesophytic species may initiate an amplifying feedback loop (Nowacki et al. 2008).

Mesophication causes forest litter changes because of decomposition rates and litter quality of mesophytic and heliophytic species, which may lower the flammability of the forest (Nowacki et al. 2008). The higher the amount of lignin in herbaceous species leaves, the slower it will decompose (Nowacki et al. 2008). Herbaceous species associated with higher lignin levels and slower decomposition rates tend be shade-intolerant, but fire tolerant species, such as oak. In contrast, shade-tolerant, but fire-intolerant mesophytic species, such as maples, have lower lignin levels and decay much faster (Nowacki et al. 2008). *L. maackii* leaf litter decomposes faster than even native mesophytic species (Trammell et al. 2012). Reductions in the amount of litter combined with remaining litter with greater moisture content enhance microclimate conditions for mesophytic seedling germination and establishment and reduce the fine fuel load necessary to carry fire through the forest floor (Nowacki et al. 2008). More fertile sites tend to be more vulnerable to the process of mesophication (Nowacki et al. 2008).

Disruptions in the understory and canopy can result in an acceleration of the mesophication process (Nowacki et al. 2008). Urbanization increases habitat fragmentation and degradation (Cameron et al. 2015). Fragmentation can result in greater occurrences of invasive herbaceous species because fragmentation results in an increase in ecosystem disturbances (Borgmann et al. 2005). *L. maackii* tends to be greater near forest edges, where fragmentation and ecosystem disturbances occur (Gorchov et al. 2014; Cameron et al. 2015). Urban-related disturbances may also reduce native herbaceous abundance and diversity (Cameron et al. 2015). Not all non-native herbaceous species that are introduced to an area will become invasive. Non-natives that occupy space acquire resources more rapidly and reduce native biodiversity (Daehler 2003). Numerous studies show that *L. maackii* may reduce native species diversity and abundance (Cameron et al. 2015). Further, human-related disturbances that increase resource availability are most likely to alter the competitive outcomes of interactions among natives and invasives (Daehler 2003).

North America's remaining temperate hardwood forests are particularly vulnerable to *L. maackii* invasion (Pipal 2014; Pennington et al. 2010). Higher densities of *L. maackii* in forest ecosystems can result in changing the structure of the forest lower canopy. It does so because *L. maackii* has greater litter fall than many native herbaceous species, affecting the microclimate. Affected factors of the microclimate include the temperature, light availability, and moisture, which have direct effects on seedling dispersal of surrounding herbaceous species (Trammell et al. 2012). *L. maackii* tends to have a longer growing season than surrounding forest species (Trammell et al. 2012). Due to increased light availability on forest floors, *L. maackii* more readily establishes itself in forests with lower herbaceous productivity rates (Trammell et al. 2012). The leachate that results from *L. maackii* leaves can also hinder the survival and seedling establishment of native herbaceous species (Trammell et al. 2012).

Trammell et al. (2012) demonstrated that there may be a trend between a forest's distance from an urban center and the occurrence of *L. maackii*, an invasive shrub (Trammell et al. 2012). This indicates that *L. maackii* is more likely to occur in urban forests influenced by urban-related disturbances. The higher occurrence of *L. maackii* in urban forests may be influenced by the heat island effect (Trammell et al. 2012).

Soils within the urban landscape may range from relatively undisturbed to highly disturbed across a small area due to varying land use (Pickett et al. 2011). Urban soils may also have varied soil textures within a small area, and disturbed urban soils may have lower water infiltration rates than undisturbed soils (Pickett et al. 2011). Soil texture has three particle-size classes. Sand-sized particles and silt-sized particles are composed of primary minerals. Clay-sized particles are composed of secondary minerals. Secondary minerals have been exposed to the weathering process (Schaetzl et al. 2005). The secondary minerals present in clay-sized particles range from phyllosilicates (kaolinite, chlorite, smectite, etc.) to quartz or other materials (Schaetzl et al. 2005). Finer-textured soils tend to have higher nutrient levels than coarser-textured soils. Soils in urban areas have been recorded to be 3 degrees Celsius (37.4 F) higher than rural areas, leading to faster litter cover decomposition rates (Cameron et al. 2015) and potentially greater levels of nitrogen (Pouyat et al. 2003). Low-nutrient soils and reduced moisture may increase the ability of natives to compete with invasives (Daehler 2003). The performance of invasives may increase in an environment with the addition of nutrients (Daehler 2003).

STUDY AREA

Figure 1. Locations of Study Sites in the Urban Forests of Rock Island, Moline, East Moline, and Silvis, IL

The study area is comprised of 36 study sites located in the urban riparian temperate hardwood forests of Rock Island, Moline, East Moline, and Silvis, Illinois. The study sites are located along overlapping gradients of remnant forest patch size, edge effect, and intensity of surrounding urban development. Patch sizes across the forests plots ranged from 9239m sq. to 2,093,17m sq.; edge effect (measured by perimeter to area ratio) ranged from 0.00664 to 0.056743. The remnant urban riparian forests of Rock Island County are similar to the hardwood forests that dominate the bluffs of the entire Upper Mississippi River region. Soils in more semi-natural urban settings, such as remnant riparian forests, have been recognized as being undisturbed as well as unusually fertile (Reichert et al. 2015).

Rock Island County consists of two Major Land Resource Area classifications, Illinois and Iowa Deep Loess and Drift, and Central Mississippi Valley Wooded Slopes. Peoria loess is the main parent material of most soils across Rock Island Co. In places across the county where the loess has eroded due to a variety of factors, the two main soil parent materials present are Illinoian till, from which Hickory soils have formed, and Pennsylvania shale, from which Marseilles soils have formed (Elmer 1998). Across the forest study sites clay content ranged from 10% to 17.5%, sand content ranged from 5% to 47.5%, and silt content ranged from 20% to 77.5%. Because two of the main parent materials, glacial till and soils formed under prairie lands, are present throughout Illinois and the Midwest, similar soils may be found in other remnant riparian forests of the Upper Mississippi River region.

METHODS

Soil samples were collected from the 36 study sites (50m radius circular plots) in the remnant urban riparian forests of Rock Island, Moline, East Moline, and Silvis, Illinois (See Figure 1). The study sites are located on a combination of city, county, and privately owned properties upon which landowner access was obtained. Arc-GIS and available geospatial databases were used to locate potential forest patches along an urbanization gradient. These study sites are part of a long-term community-based Sustainable Urban Forest Project being conducted by the Upper Mississippi Center of

Sustainable Communities. Herbaceous native and invasive cover, *L. maackii* cover, garbage cover, and soil litter cover was measured using line-point intercept along six transects within each study site using a spoke design. Native cover refers to total native herbaceous cover. Invasive cover refers to total invasive herbaceous cover, excluding *L. maackii*. Herbaceous cover refers to total herbaceous, including native and invasive species.

A composite soil sample was collected from each of the 36 forest plots from several random locations within the 50m radius plot at 0-15cm depth. All of the collected soil at each site was mixed to ensure a homogenous sample. Each mixed soil sample was placed into a labeled 1lb coffee bag.

The soil samples were sent to the University of Missouri-Extension Office Soil Testing Lab. Two tests, soil organic matter (SOM) and soil texture were run. SOM refers to the percent of organic matter, or carbon, contained within each sample. Soil texture refers to the soil particle size. Clay content refers to the percentage of clay soil texture contained within each soil sample. Sand content refers to the percentage of sand soil texture contained within each soil sample. Silt content refers to the percentage of silt soil texture contained within each soil sample.

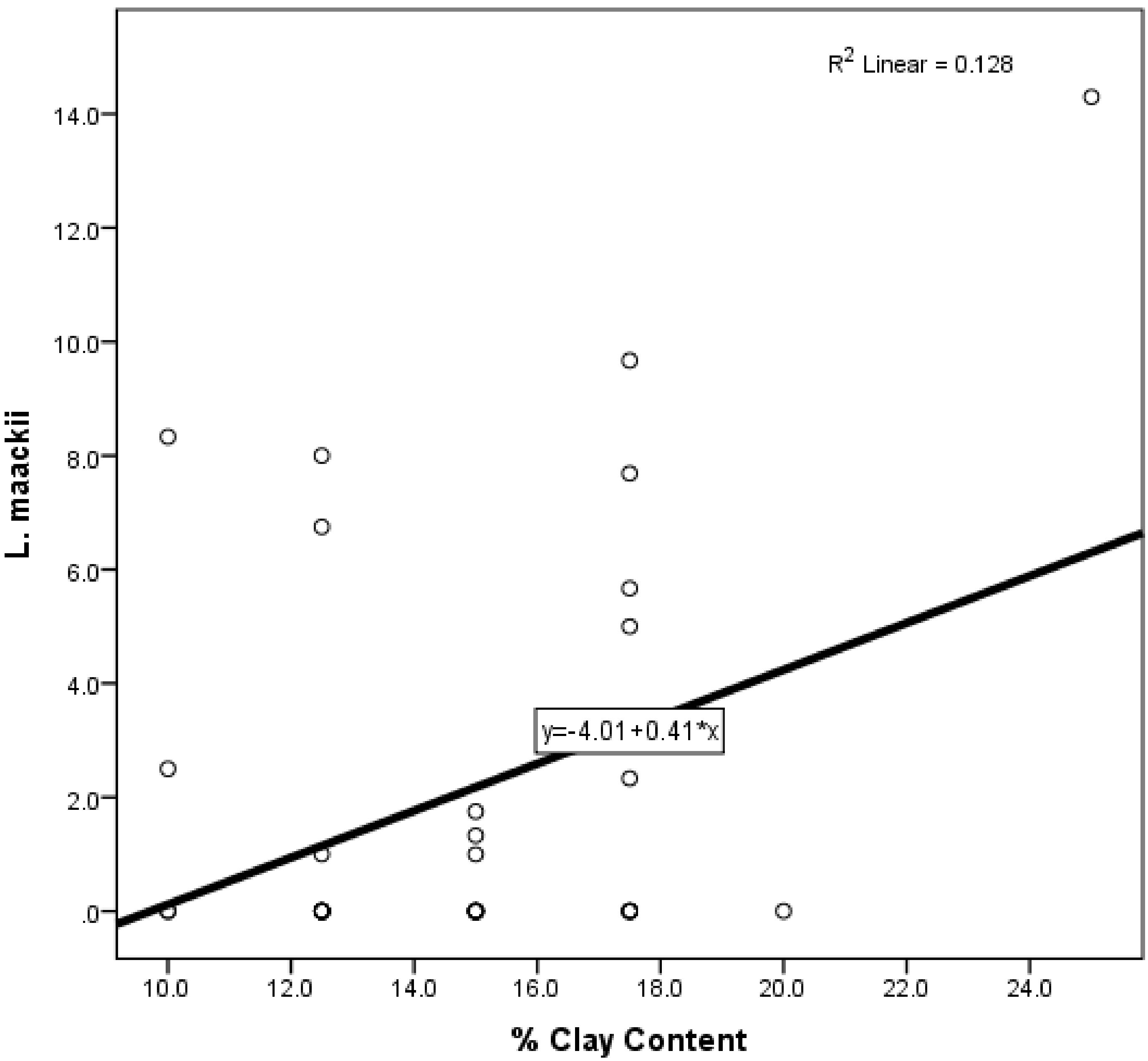
ArcGIS and geospatial data was used to calculate forest patch size (measure of level of habitat fragmentation), perimeter to area ratio (measure of edge effect), and % impervious surface (measure of intensity of urbanization), % forest cover, % green (parks) and other open space (cemeteries, golf courses), and % total urban forest canopy cover within 400 meters of the center of each study site.

IBM SPSS statistics 23 software was used to analyze the data and identify significant (p-value< 0.05) bivariate correlations between *L. maackii* cover and the following predictors: (1) soil properties (%sand, %silt, %clay content, % SOM, %litter cover); (2) urbanization-related disturbances (patch size, perimeter to area ratio, garbage cover, and % impervious surface); (3) abiotic factors (slope; and (4) biotic factors (% forest cover, % green and other open space, % total urban forest canopy cover, native cover, invasive cover, herbaceous cover). Linear regression models were run on statistically significant (P-value= <0.05) correlations that were found between *L. maackii* cover and predictors.

RESULTS

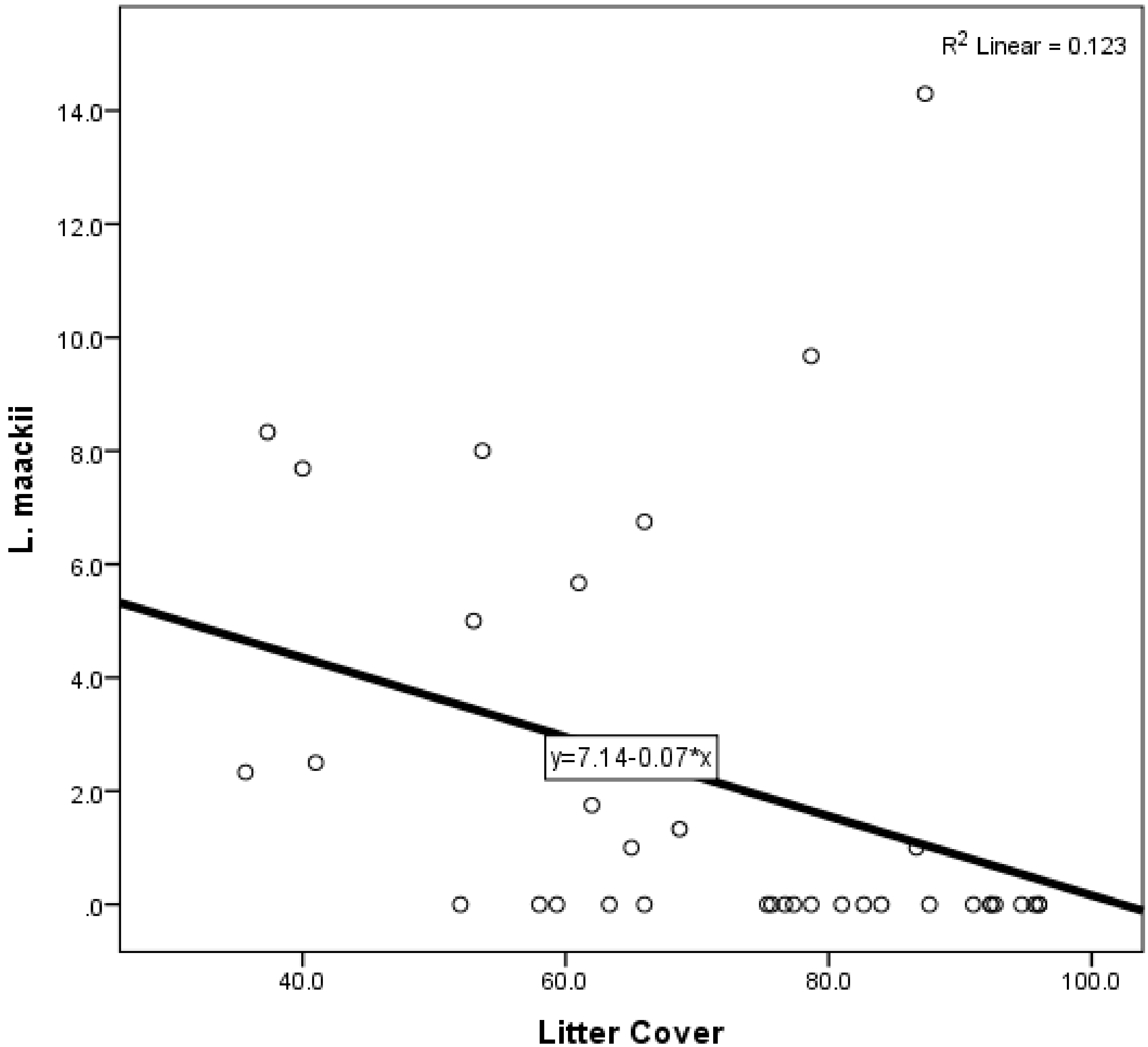
There was a strong positive relationship (r= 0.358) between **%** clay soil content and *L. maackii* cover, soil clay content explained 12.8% of the variation in *L. maackii* cover across sites, (R2= 0.128, F= 4.992, P-value =0.032);

Figure 2. The relationship between *L. maackii* cover and clay content.



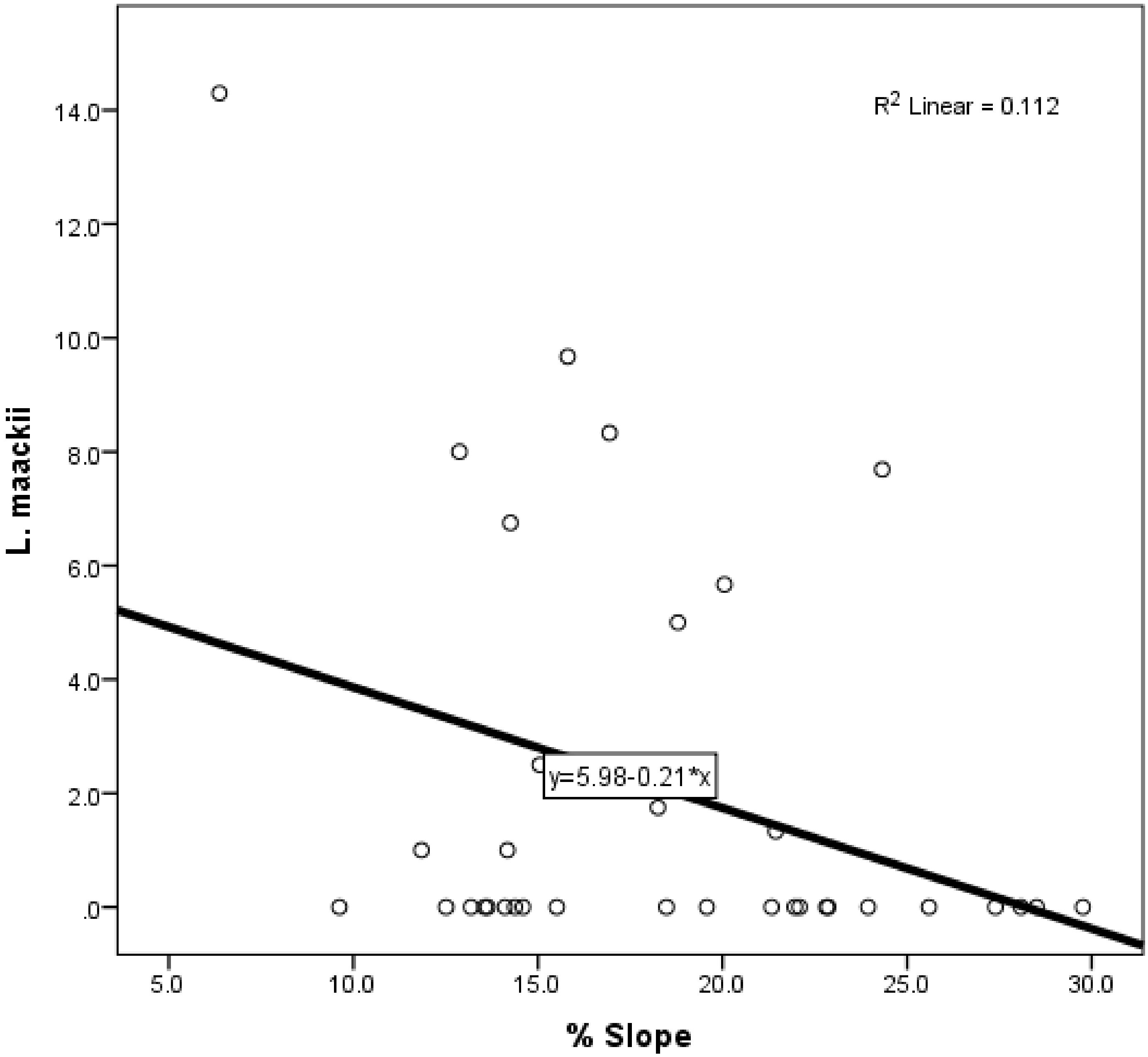
There was a strong negative relationship (r= -0.350) between litter cover and *L. maackii* cover, and litter cover explained 12.3% of the variation in *L. maackii* cover across sites, (R2= 0.123, F= 4.755, P-value= 0.036);

Figure 3. The relationship between *L. maackii* and litter cover.



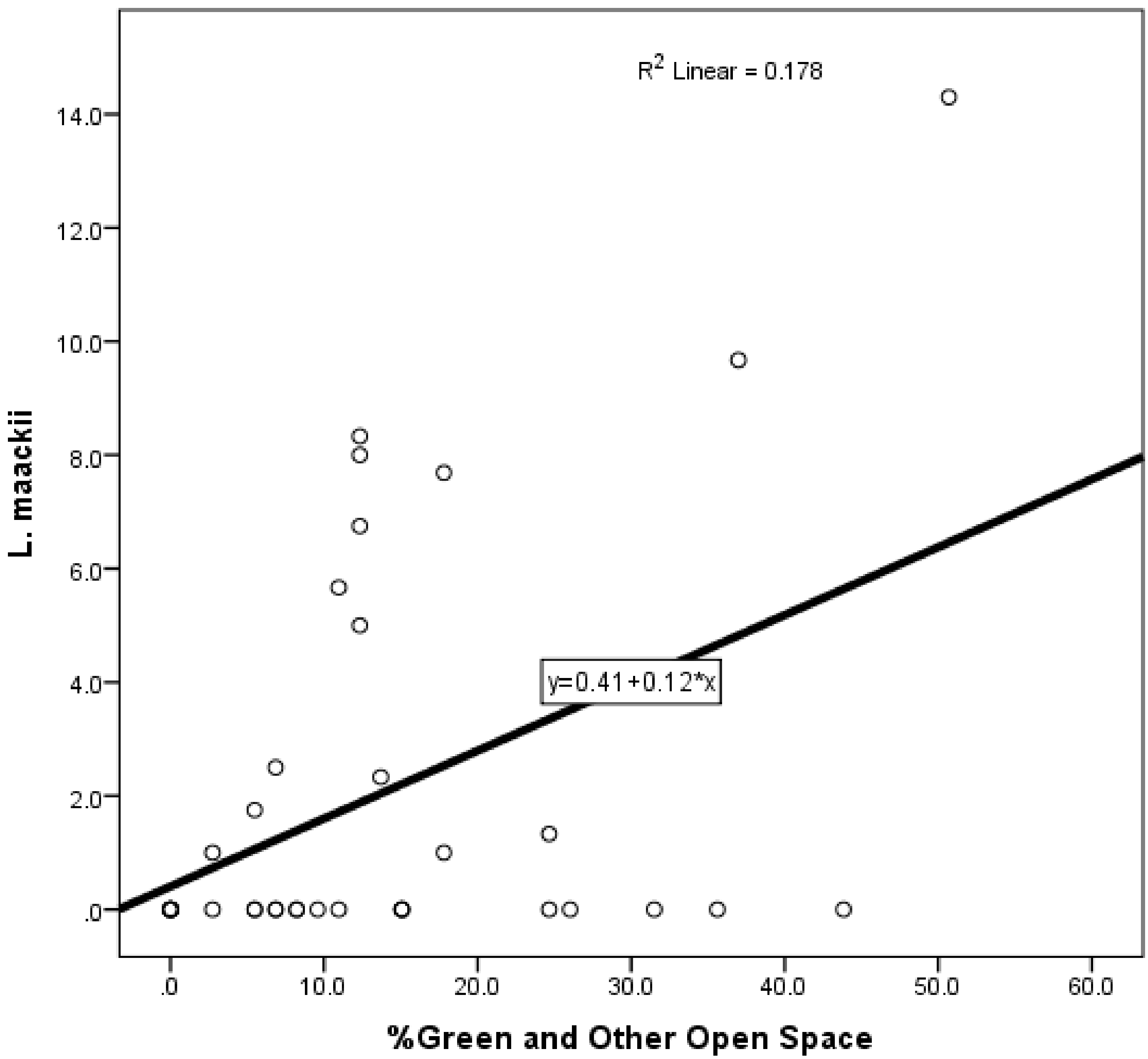
There was a strong negative relationship (r= -0.355) between slope and *L. maackii* cover, and slope explains 11.2% of the variation in *L. maackii* cover across sites (R2= 0.112, F= 4.284, P-value= 0.046);

Figure 4. The relationship between *L. maackii* cover and percent of slope.



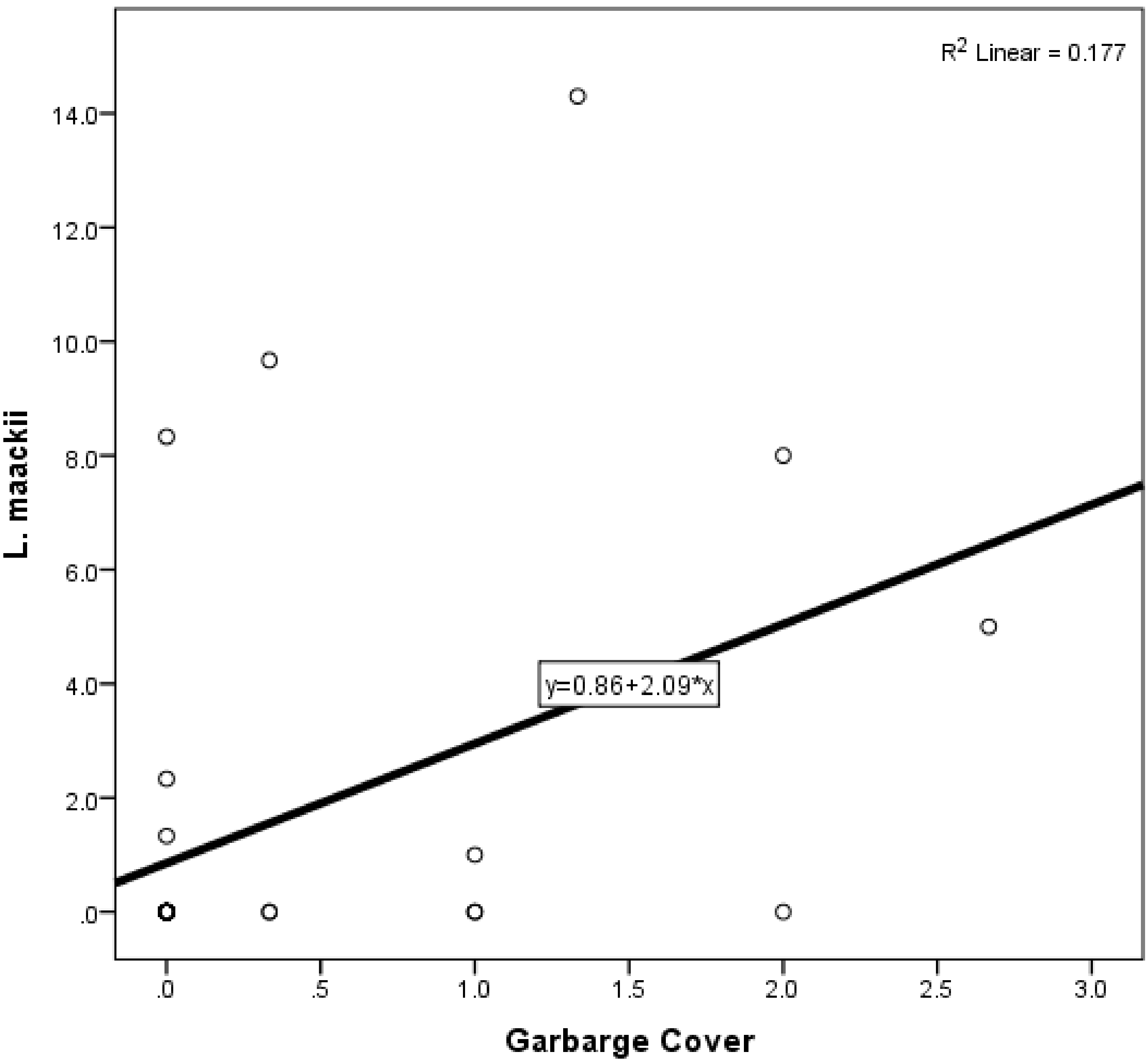
There was a strong positive relationship (r= 0.422) between %green and other open spaces and *L. maackii* cover, and green and other open spaces explained 17.8% of the variation in *L. maackii* cover across sites, (R2= 0.178, F= 7.358, P-value= 0.010);

Figure 5. The relationship between *L. maackii* cover and %green and other open spaces.



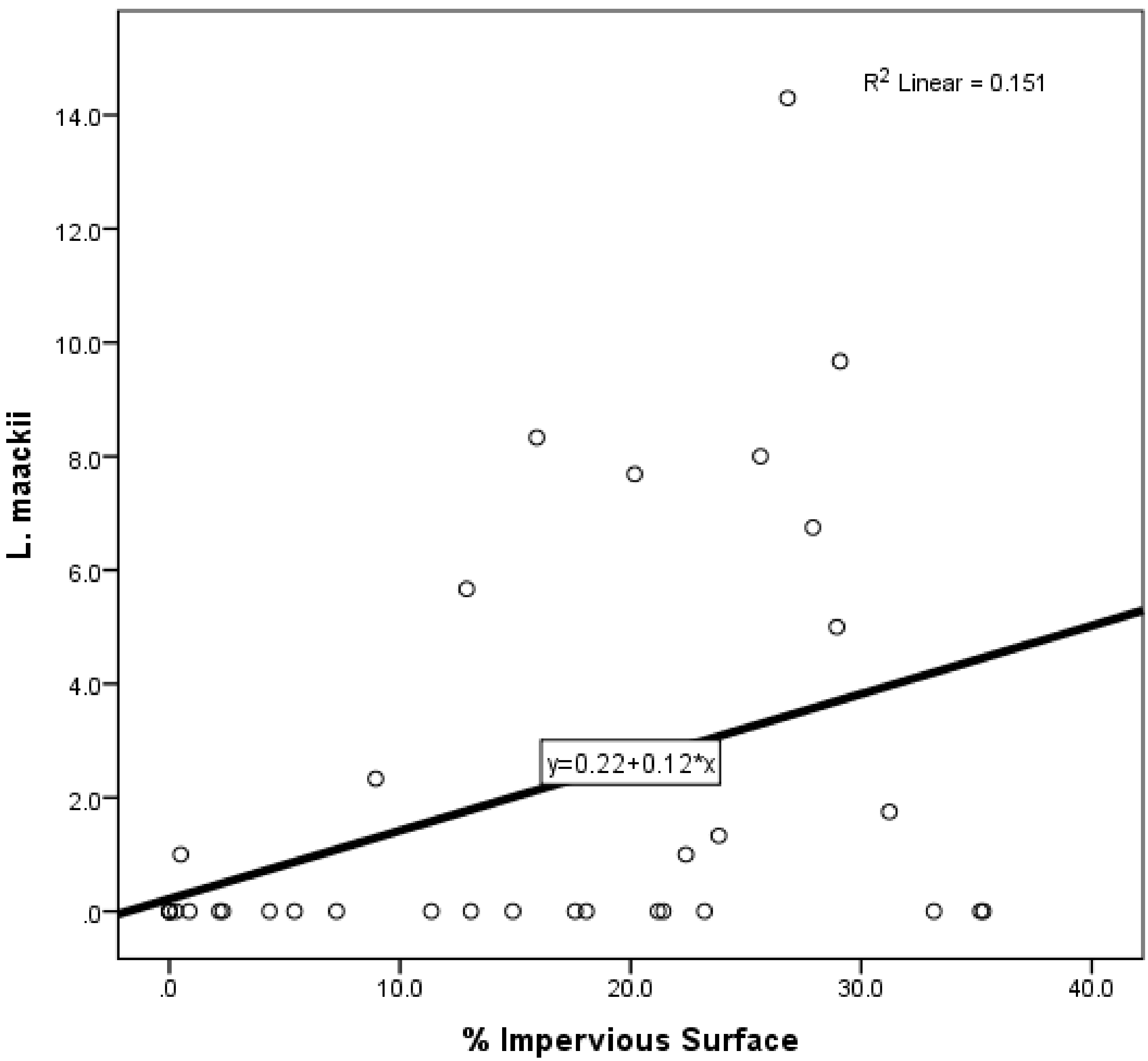
There was a strong positive relationship (r= 0.420) between garbage cover and *L. maackii* cover, and garbage cover explained 17.7% of the variation in *L. maackii* cover across sites, ($R2$= 0.177, F= 5.798, P-value= 0.023);

Figure 6. The relationship between *L. maackii* cover and garbage cover.



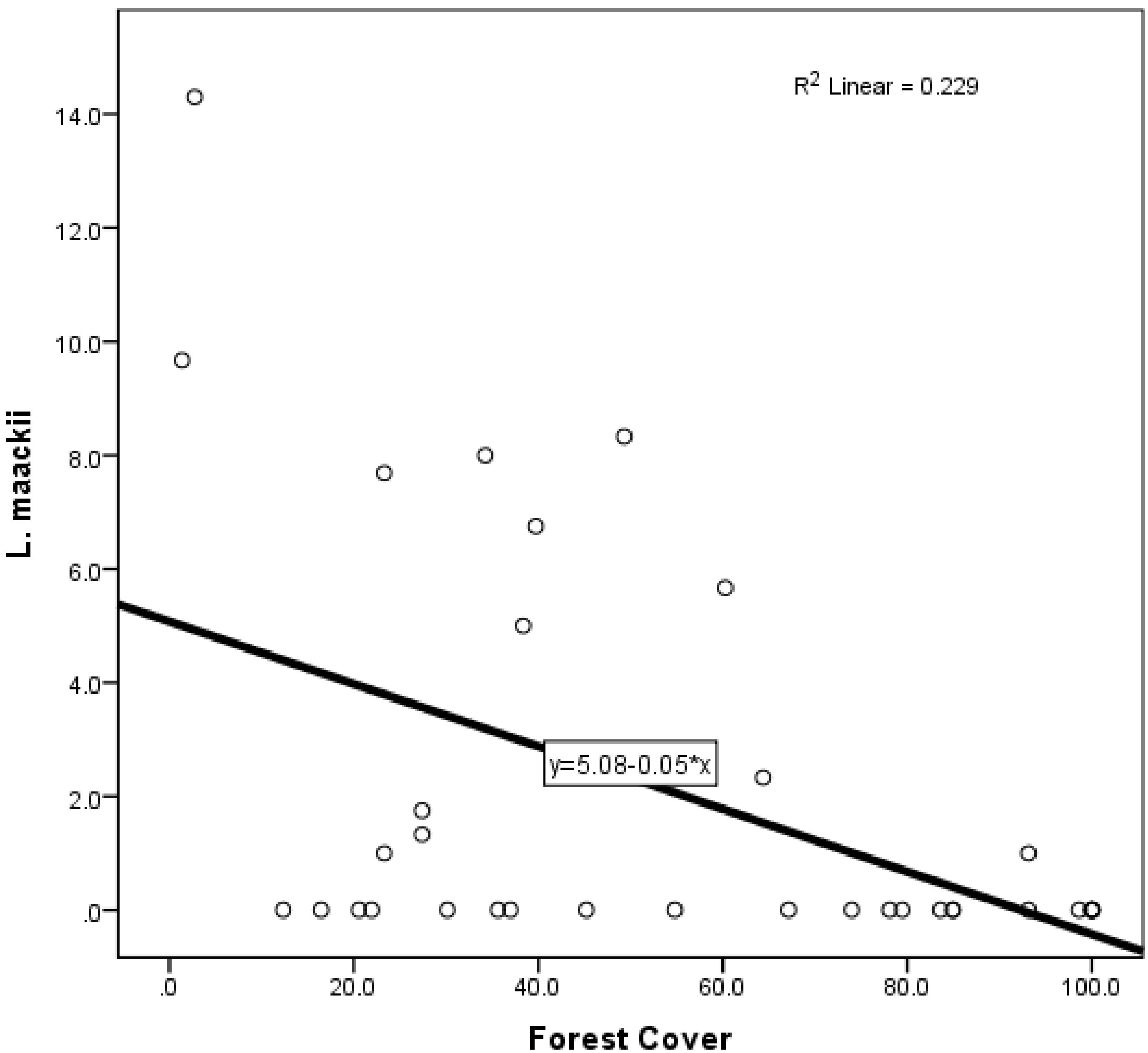
There was a strong positive relationship (r=0.388) between % impervious surface and *L. maackii* cover, and %impervious surface explained 15.1% of the variation in *L. maackii* cover across sites, (R2= 0.151, F= 6.033, P-value= 0.019).

Figure 7. The relationship between *L. maackii* cover and % impervious surface.



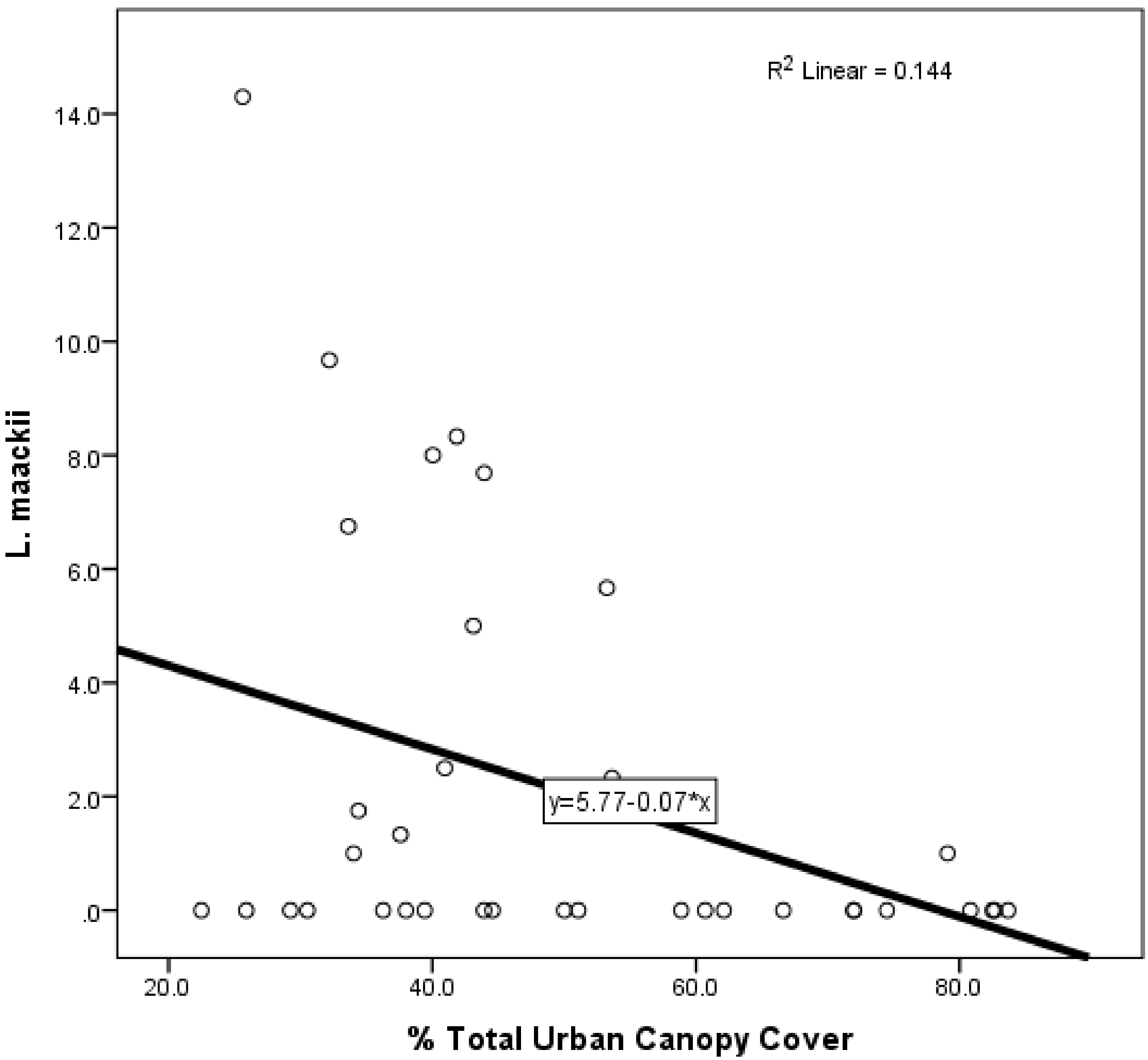
There was a strong negative relationship (r=-0.479) between forest cover and *L. maackii* cover, and forest cover explains 22.9% of the variation in *L. maackii* cover across sites, (R2= 0.229, F= 10.102, P-value= 0.003);

Figure 8. The relationship between *L. maackii* cover and forest cover.



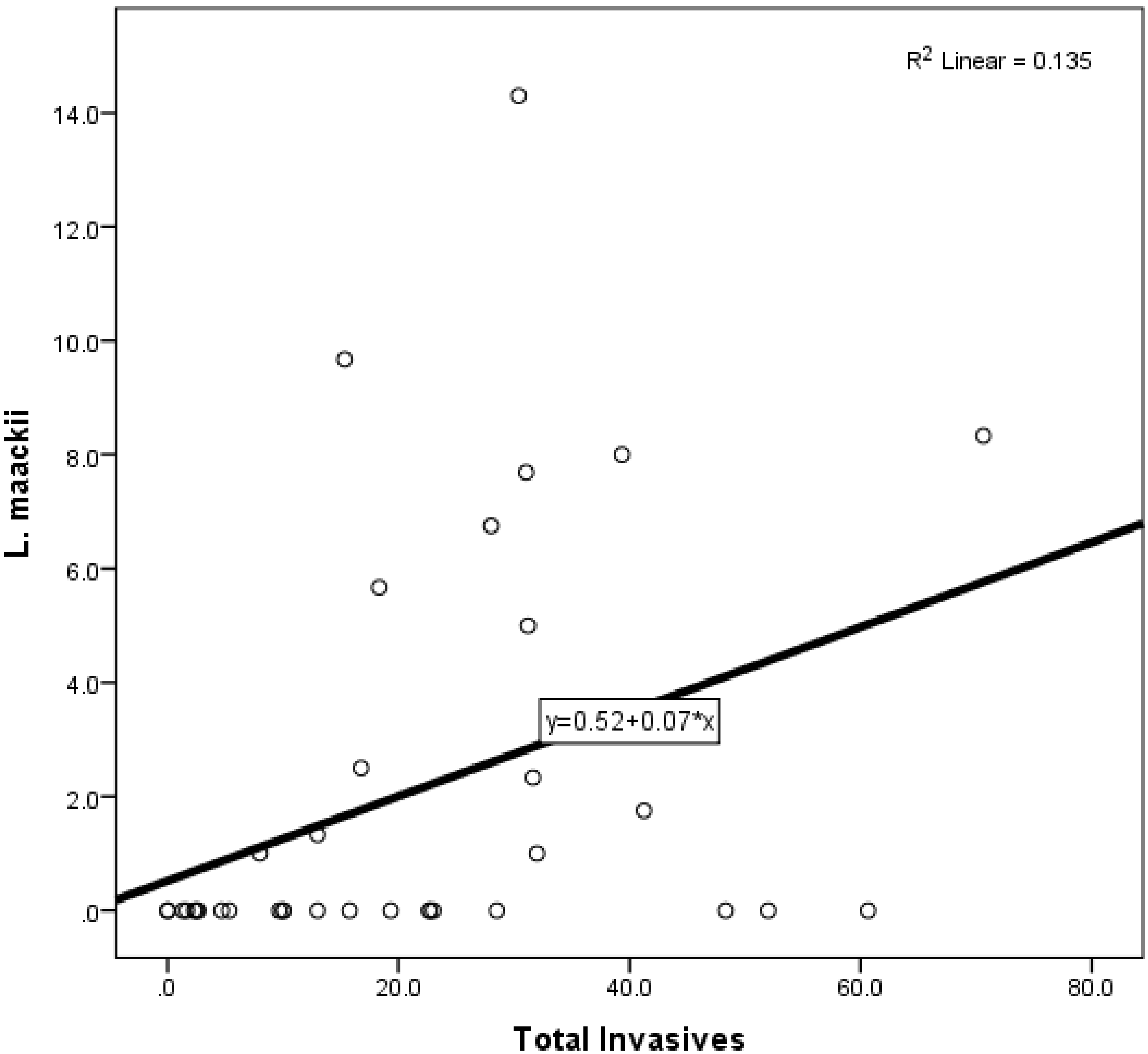
There was a strong negative relationship (r= -0.359) between total urban forest canopy and *L. maackii* cover, and total urban canopy cover explained 14.4% of the variation in *L. maackii* cover across sites, (R2= 0.144, F= 5.718, P-value= 0.022);

Figure 9. The relationship between *L. maackii* cover and total urban canopy cover.



There was a strong positive relationship (r= 0.367) between *L. maackii* cover and other invasive cover and invasive cover explains 13.5% of *L. maackii* abundance across sites, (R2= 0.135, F= 5.288, P-value= 0.028);

Figure 10. The relationship between *L. maackii* cover and other invasive cover.



There was no significant relationship between *L. maackii* cover and total native cover or total herbaceous cover (P-value>0.05).

DISCUSSION

The results of this study suggest that there is no single driver of *L. maackii* invasion across 36 urban riparian forest plots in Rock Island County, IL. However, a number of biotic and abiotic variables were found to have a significant effect on *L. maackii* abundance throughout these sites. My findings suggest that numerous environmental, biotic, and urban-related disturbances are moderately influencing *L. maackii* invasion. In decreasing order of influence, these factors are forest cover, green and other open spaces, garbage, impervious surface, total urban forest canopy cover, total invasive herbaceous cover, clay soil texture, litter, and slope. Increasing impervious surface and greater garbage cover was found to be associated with an increase in *L. maackii* cover. Although remnant forest cover and total urban forest canopy cover were associated with a decrease in the magnitude of the invasion, green and other open spaces were associated with an increase in *L. maackii* cover. Although there was no relationship between *L. maackii* cover and total native herbaceous understory cover, there was a strong positive relationship between *L. maackii* cover and invasive cover. Increasing *L. maackii* cover has a significant relationship with reduced litter cover.

I observed a strong positive relationship between *L. maackii* cover and the clay content of the soil. Conversely, there was a strong negative relationship between *L. maackii* cover and slope. Flat or gently sloping sites and sites characterized by finer-textured soils appear to be inherently more vulnerable to invasion. Flat or gently sloping sites are likely characterized by deeper, more nutrient-rich soils (McEwan et al. 2012), which can promote the establishment of exotic species (Dallimer 2012). Importantly, increasing *L. maackii* cover was strongly associated with a decrease in litter cover. Lower litter levels may be the result of *L. maackii*'s leaves decaying faster than surrounding natives (Trammell et al. 2015; Pipal 2014). The Midwestern landscape was once dominated by a fire regime that relies on fuel and open canopies (Nowacki et al. 2008). Litter serves as a fuel in xerophytic systems by creating heat and aeration for fires to carry throughout forests, and open canopies provide more light to create higher heat and more fire-ready forests (Nowacki et al. 2008). Since *L. maackii* abundance is associated with lower litter levels and creates dense monocultures in areas that otherwise would have higher light availability (Pipal 2014) My findings suggest that, *L. maackii* may be accelerating site mesophication and the feedback associated with such process may seriously reduce the effectiveness of prescribed fire as a forest restoration tool in the Midwest.

I found strong positive relationships between impervious surface, garbage levels, and green (parks) and other open spaces (golf courses, cemeteries) and *L. maackii* cover. All three of these factors not only fragment remnant forest habitat but are also associated with disturbances that create gaps in the remnant forest canopy (Pipal 2014; Dallimer et al. 2012). Forest cover and the percentage of total urban canopy cover were found to have strong negative relationships with *L. maackii* cover. Urbanization results in greater ecosystem fragmentation and disturbances, allowing for the greater establishment of invasive herbaceous species. Fragmentation increases light availability (Borgmann et al. 2005), and the findings of my study indicate that light availability may be a significant factor effecting L. maackii establishment. L. maackii abundance is greater in areas where %total urban canopy cover is lower and light availability is higher. These findings are consistent with other studies that show that *L. maackii* favors establishment in areas where light availability is high (Pipal 2014). My findings are somewhat inconsistent with the findings of Borgmann et al. (2005) study that did not find strong relationships between *L. maackii* invasion and light availability (Borgmann et al. 2005). However, this may be explained by *L. maackii's* longer leaf phenology, which allows for its leaves to receive light when the rest of the forest's canopy is bare (Pipal 2014; Borgmann et al. 2005). Thus, *L. maackii* may survive in areas with lower lighter availability because of their extended leaf phenology but *L. maackii* establishment may be favored in areas with high light availability as are those characterized by high levels of fragmentation and urbanization (%impervious surface, garbage, and green and other open spaces). Future studies may need to be conducted directly relating light availability and the magnitude of *L. maackii* invasion to determine whether light availability is a driving factor of *L. maackii* establishment or if there is another driving factor related to open habitats.

I observed a strong positive relationship between *L. maackii* and other invasive cover in forest understories. I found no significant relationship between *L. maackii* cover and total native cover. This finding is inconsistent with other studies that have found negative relationships between native herbaceous species and *L. maackii* in urban riparian forests (Borgmann et al. 2005). Borgmann et al. (2005) also found no significant relationship between *L. maackii* and native herbaceous species. One explanation for finding no significant relationship may be that I measured native species abundance, not diversity. Further, Cameron et al. (2015) demonstrated that *L. maackii* abundance did not have a strong relationship with native diversity or abundance once the invasion was widespread in the region, which is certainly the case in this study (Cameron et al. 2015). Future studies should consider further examining the relationship between native diversity and *L. maackii* abundance.

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