

RESEARCH ARTICLE

Legacy effects of long-term autumn leaf litter removal slow decomposition rates and reduce soil carbon in suburban yards

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Societal Impact Statement

As cities grow, it is essential to understand how landscape management decisions in urban spaces alter ecosystem function. This study demonstrates that the ubiquitous practice of long-term leaf litter removal in suburbs, even in relatively small patches of a yard, reduces the soil's ability to cycle nutrients in plant litter and results in lower amounts of carbon stored in the soil. Even two years of retaining leaves where they previously were removed is insufficient to restore decomposition rates or carbon pools. This research is an important step in creating best practices for litter management to maintain essential ecosystem functions, like carbon sequestration, water holding capacity, and soil fertility.

Summary

- Seasonal senesced leaf litter removal eliminates considerable organic material from suburban soils annually. We test if this disturbance alters decomposition and carbon cycles and depletes soils of organic matter over time, creating persistent legacy effects.
- We used a factorial experimental design to implement 1–2 years of current leaf litter manipulations (remove or retain fallen leaves) within historically raked and unraked areas in suburban Maryland yards. We then compared total organic soil carbon and decomposition using a standardized substrate decomposition methodology (Tea Bag Index) across treatment plots.
- Long-term litter removal in suburban yards reduced decomposition rates by 17% and total soil organic carbon concentration by up to 24% compared to areas where leaf litter was retained in situ. In contrast, short-term management changes (1–2 years) did not significantly impact decomposition rates or total organic soil carbon concentrations.
- Our findings suggest that long-term suburban litter raking creates legacy effects that alter decomposition and carbon storage process trajectories that are not easily reversed. This is important in understanding urban ecosystem function and sustainable management.

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KEYWORDS

decomposition, leaf litter management, legacy effects, raking, soil carbon, Tea Bag Index, urban ecology

1 | INTRODUCTION

By 2050, an estimated 68% of the world's population will live in urban areas (United Nations et al., 2019). Unfortunately, urban areas often have degraded ecosystems with poor air quality, heat island effects, large amounts of runoff, and other environmental concerns (Pickett et al., 2011). Urban trees can improve urban ecosystems and quality of life for human residents by reducing temperatures and stormwater runoff, decreasing particle pollution, and sequestering carbon (Nguyen et al., 2017; Pataki et al., 2021; Roy et al., 2012). Urban trees' viability depends on soil health, but little attention has been given to the linkages between urban trees and urban soils. Urban yard management practices can modify soil organic matter through inputs like fertilizer, mulch, and compost or by removing plant material, such as leaf litter and grass clippings. Understanding how yard management mediates soil processes is essential for sustaining urban forests and their ecosystem services.

Thirty-five million tons of yard waste from grass clippings and leaf litter are removed annually from urban and suburban landscapes (EPA, 2020). Soil carbon and decomposition rates increase in lawns when grass clippings are retained (Kopp & Guillard, 2004; Qian et al., 2003). An estimated 52% of litterfall carbon is removed each year from the city of Boston, MA (Templer et al., 2015). In Minneapolis, Minnesota, 11% of residential carbon output is due to yard waste removal (Fissore et al., 2012). These examples make clear that a large amount of carbon in the form of green and senesced plant material is removed annually from yards and other managed urban spaces. The scale and regularity of this disturbance create the potential for cumulative impacts on urban decomposition rates and soil carbon content. However, little research has examined the role leaf litter management practices play in urban soil processes.

Senesced leaf litter removal could alter soil organic carbon concentrations (SOC) in residential lawns through the direct reduction of inputs or indirectly by altering decomposition rates. Forest experiments show that long-term litter removal decreases SOC (Lajtha et al., 2018; Xu et al., 2021). There is also evidence that reducing leaf litter reduces decomposition rates (Fung et al., 2022; Lu et al., 2021) and soil respiration (Xu et al., 2013), perhaps by slowing carbon-limited microbial processes. Litter removal could also impact decomposition processes by reducing habitat complexity for detritivore communities (Lamano Ferreira et al., 2018; Ossola et al., 2016). Abiotic factors could be altered by litter removal as well. Temperature and moisture variability often increase when litter is removed (Sayer et al., 2020). If litter removal reduces the buffering of abiotic factors, it could filter microbial communities, removing more sensitive groups.

Leaf fall in urban and suburban areas is often managed consistently by residents for long periods of time—based on homeowner preferences, homeowner association bylaws, or city guidelines—creating the potential for cumulative effects of management decisions

on ecosystem function. Effects that persist even after management or disturbance has ceased, legacy effects, have been documented in forested ecosystems. In the Middle Ages, leaf litter in Swiss forests was raked for hundreds of years for use as livestock bedding. Litter removal ceased at the end of the 19th century, yet SOC is still 17% lower today than in unraked forests (Gimmi et al., 2013). While continuous management can lead to legacy effects, active or recent changes in management regimes could interact with historical management decisions to change decomposition and carbon outcomes in interesting ways. For example, the presence of litter where it had been previously removed may trigger priming effects and increase decomposition rates of recalcitrant material (Kuzayakov, 2010; Pisani et al., 2016). Thus, multiple, co-occurring mechanisms could shape the impact of historical and current leaf litter management on decomposition and carbon storage processes in cities and suburbs.

Here, using a paired factorial experiment in suburban yards, we directly test whether historical litter removal practices in residential yards lead to legacy effects on decomposition rates or SOC and whether these processes change when alternative litter management practices are initiated. There are three potential primary outcomes, which would be driven, respectively, by current management (Figure 1a), historical management (Figure 1b), and an interaction between current and historical management (Figure 1c). Consistent with Figure 1b, we hypothesized that areas where leaves had been continuously removed (historically removed) would have slower decomposition rates due to decreased microbial activity but smaller SOC pools because of the overall lack of litter inputs compared to areas where leaves were retained (historically retained). We expected that the effects of new alternative manipulations would be relatively small compared to the effects of historical management.

2 | MATERIALS AND METHODS

2.1 | Study sites

Residents managing suburban yards in Maryland, USA, were recruited to join the study through environmental organizations, neighborhood list-servs, and word-of-mouth. Out of 100 residents who completed an interest form, site visits were completed for 33 homes that fit the initial criteria. Ultimately, 13 suburban yards located between Washington, DC, and Baltimore, MD, were selected for the study based on consistent criteria, with most homes in the College Park, MD, and Columbia, MD, areas (Figure 2a). Specifically, all selected homes had an area of the yard where leaf litter was retained (historically retained)—often in the backyard or near a tree line—and an area of the yard where leaf litter was removed (historically removed) (Figure 2b). The two historical management areas within a yard shared at least one canopy tree species,

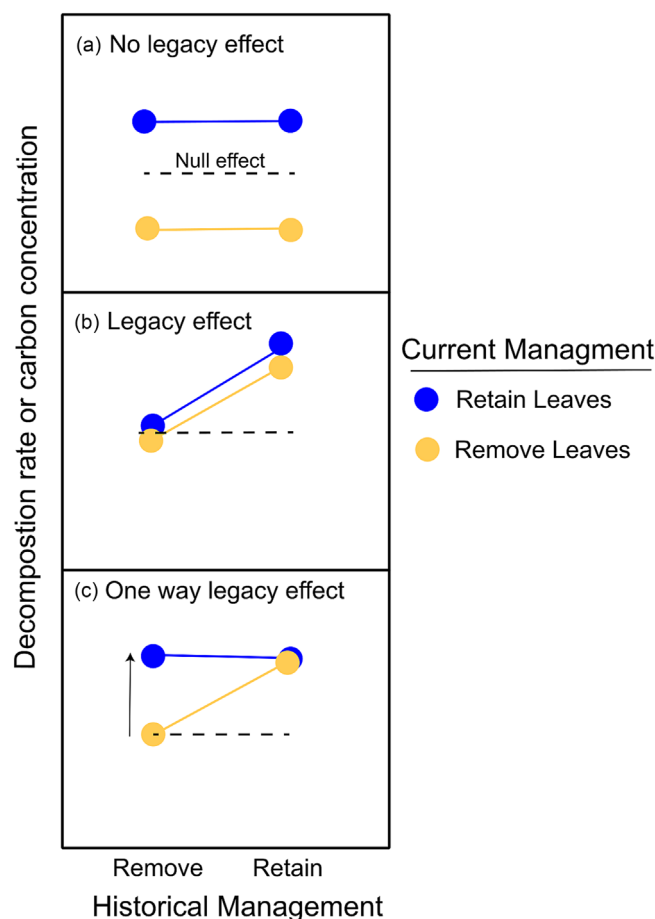


FIGURE 1 Conceptual diagram of three possible responses of soil organic carbon concentration or decomposition rate of historical management and current leaf fall manipulations in suburban yards. It could be that there is no legacy effect, only an effect of current management practice (a). Alternatively, there may be no effect of current management but a legacy effect from historical management (b). Finally, there may be an interactive outcome where the effect of current management is dependent on historical practices (c).

and neither were fertilized nor treated with pesticides. If turfgrass was present, it was not mown for the duration of the experiment. These respective management areas had been managed consistently for 3–30 years, with a median duration of 11 years. However, this timeframe was self-reported by homeowners and could be an underestimate depending on the practices of previous tenants unknown to current residents. A disregarded unraked area of the current tenant likely was also unraked by previous tenants. For this reason, we also identified the construction year of each home using publicly available parcel data. Homes were built between 1924 and 2001.

2.2 | Experimental set-up

At each home, we used a factorial design to cross historical and current litter manipulations creating four treatment combinations in each yard (Figure 2b): historically removed/currently removed, historically

removed/currently retained, historically retained/currently retained, and historically retained/currently removed.

We implemented these treatment combinations in November of 2020 in all 13 yards. Fallen leaves from each $1 \times 2 \text{ m}^2$ historical management plot were raked and weighed. Then half of the fallen leaf biomass was returned to the 1 m^2 half of the plot where leaf litter was retained for the current management treatment. Leaves were contained with a 15 cm tall mesh edging material around the outside of each plot and a wide mesh covering to preserve leaves from wind loss over the winter. The same treatment process was repeated in a subset of the yards ($n = 6$) in November 2021 for a second year of the manipulation. We collected percent canopy cover data using the Canopeo application (Patrignani & Ochsner, 2015) and total litter biomass data from each historically managed area of the yard.

2.3 | Decomposition assay

In each of the four treatment plots in a yard, we quantified the decomposition rate (k_{TBI}) of a common senesced plant material substrate using the standard Tea Bag Index protocol (Keuskamp et al., 2013). The Tea Bag Index is designed to collect uniform decomposition data across a range of ecosystem types. It uses green and rooibos Lipton® tea enclosed in teabags that are pre-weighed and buried at a depth of 8 cm for 90 days before being dried and re-weighed. The Tea Bag Index has been used in over 2000 sites, and its methodology including the equation guides is found here: <http://www.teatime4science.org>. Note that in 2017, Lipton® tea changed the teabag material, but the tea leaf content did not change. This change has not been found to affect the Tea Bag Index calculations (Middelantis et al., 2023). The calculations are shown below. A stabilization factor (S), calculated as

$$S = 1 - \frac{\left(1 - \frac{\text{final mass Green}}{\text{initial mass Green}}\right)}{\text{Green hydrolysable fraction}},$$

is used to estimate the ratio of actual decomposed material to possible hydrolysable material in green tea. Stabilization (completion of labile decomposition) will be reached in the green tea after 90 days, and it is assumed that the stabilization factor will be the same for the rooibos tea after accounting for its own hydrolysable fraction.

The Tea Bag Index calculates the decay rate (k_{TBI}) from mass loss after t days ($W_r(t)$), the labile fraction of rooibos tea ($a_r = 1 - S$), and recalcitrant ($1 - a_r$) fraction of rooibos tea using the following equation:

$$W_r(t) = a_r e^{-k_1 t} + (1 - a_r)$$

In 2021, two replicates of green and rooibos tea were used in each treatment plot. This totaled eight green and eight rooibos teabags per yard, split across the four treatments. Teabags were buried in March 2021 and removed in June 2021 (90-day duration) at all

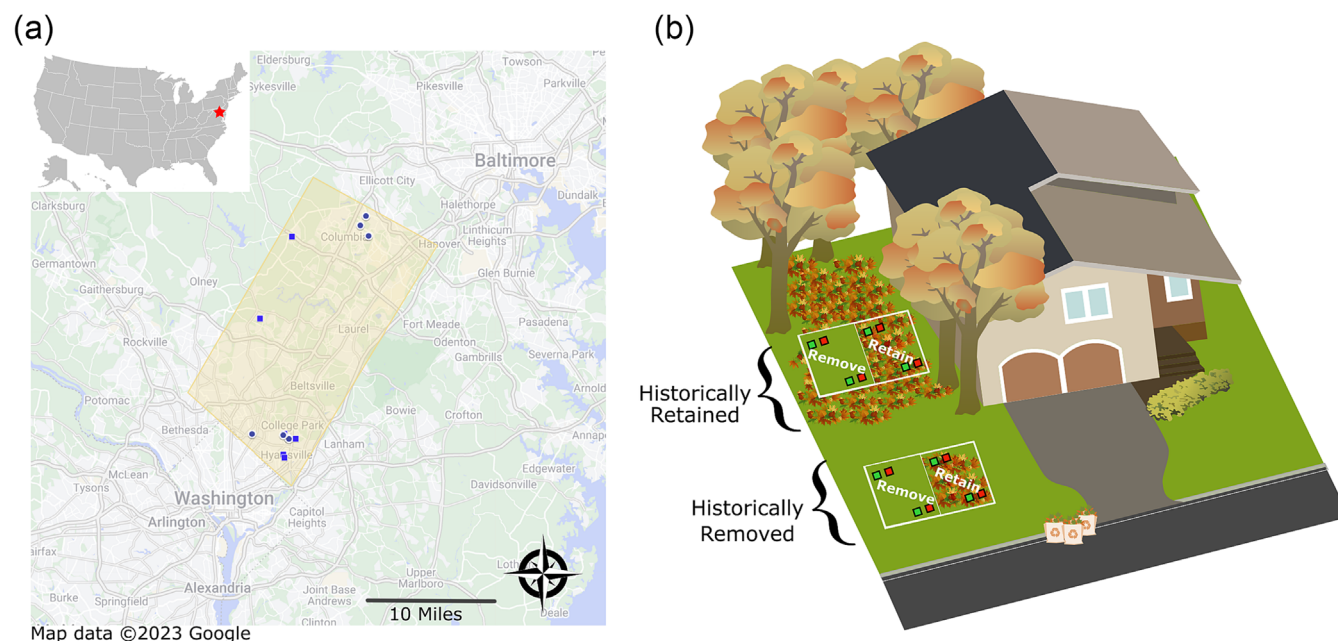


FIGURE 2 Study site map and experimental set up at each home. (a) This study took place between Washington, DC, and Baltimore, Maryland (yellow shade). All yards (points) were used in 2021; a subset of six yards (denoted by square points) continued the study in 2022. (b) Each yard contained an area where leaf litter was historically retained and removed. We set up two adjacent plots in each historical management type, each 1×1 m in size. In one plot, we removed leaf litter, and in other plot, leaves were retained. Rooibos and green tea bags were buried in the corners of each plot for decomposition assays, as indicated by green and red squares. This composite figure integrates individual vector graphics created by Jane Hawkey and Tracey Saxby, Integration and Application Network (ian.umces.edu/media-library). [Correction added on 6 March 2024, after first online publication: The attribution of Figure 2 has been added in this version.]

13 houses. The procedure was repeated in the six homes that continued with the study from March–June 2022. However, in 2022, each treatment plot had three replicates of green and rooibos tea. In total, we used 152 teabags. Over the 2 years, we lost 2 red teabags and 11 green teabags. In addition to lost teabags, the k_{TBI} decay rate was incalculable using the TBI equations for eight rooibos-green teabag pairs due to the rooibos tea entering the second phase of decomposition.

2.4 | Soil carbon sampling

We collected 1.3 cm diameter soil cores to a depth of 18 cm to measure SOC concentration in both historical treatment areas from all 13 yards, in March 2021. The initial soil samples were only taken in the historical treatment plot (retain and remove areas)—as litter in the current year experimental treatments had not yet had a chance to decompose and alter soil processes. In June 2021 (13 yards) and June 2022 (6 yards), samples were taken in each current treatment plot to determine whether changing leaf fall management practices altered SOC. Samples were dried, ground, and analyzed for total soil organic carbon concentration using a LECO CN628 analyzer (LECO Corporation, St. Joseph, MI). We verified that carbon content was driven by organic not inorganic carbon by testing powdered samples for effervescence with 4 M HCL drops.

2.5 | Statistical analyses

All analyses were completed in R (v. 4.3.1). Generalized linear mixed models with random effect structures were performed using the “lmer” command in the “lme4” package (Bates et al., 2015). We used the “Anova” function from the “car” package to create Anova-like tables to evaluate our models using Type III Wald chi-square tests (Fox & Weisberg, 2019). We used the “emmeans” package to conduct post hoc tests using estimated marginal means with a Tukey adjustment (Lenth, 2023). We used the “cor.test” function from the “stats” package to calculate Pearson’s product moment correlation coefficients for canopy cover and litter mass. To verify assumptions, we assessed residuals using QQ plots from the DHARMa package (Hartig, 2022).

We built linear mixed models to evaluate the effect of historical and current leaf litter management on decomposition. We calculated a decay constant (k_{TBI}) for each rooibos/green teabag pair and then averaged the decay constant by treatment plot. Historical management, current management, and their interaction were included as fixed effects. Year and yard were included as random intercepts to account for variation between study years and individual houses.

We used a similar model structure to evaluate the effect of historical and current management on the tea mass percent loss (averaged by replicate) but with an additional fixed effect to account for the type of tea (green or rooibos) and all two-way interactions.

We used two models to evaluate the effect of management on SOC concentrations. We analyzed the pre-treatment soil samples

taken at all 13 houses in March 2021 to test for historical management legacy effects. We evaluated the fixed effect of historical management on SOC, with “yard” as a random effect. To test the effects of current management, we used SOC from soil samples from 19 houses collected in June 2021 (13 yards) and June 2022 (6 yards). Our model structure included fixed effects of historical management, current management, and their interaction. As with all other models, we included “year” and “yard” as random effects to account for variation between yards and years. We considered a 0.05 alpha value as the threshold for strong evidence of an effect and 0.1 as the cutoff for weak evidence.

3 | RESULTS

Canopy cover in each historically managed area ranged from 2.5% to 84.4%, with a mean canopy cover of 44.7%. Areas where leaves were historically retained had $51.9 \pm 6.7\%$ canopy cover, exceeding the $37.5 \pm 7.4\%$ average in areas where leaves were historically removed. Litter mass averaged $750 \pm 81.9 \text{ g/m}^2$ in historically retained areas and $363 \pm 46.3 \text{ g/m}^2$ in historically removed areas. It is important to note that there have historically been no leaves in historically removed areas in unmanipulated conditions, so prior litter inputs are zero in that treatment. The biomass measurement provided above only refers to the quadrats in each historic area where leaves were currently retained that year (i.e., the historically retained, currently retained treatment quadrat vs. the historically removed, currently retained treatment quadrat). Canopy cover was not strongly correlated with litter mass ($r_{24} = 0.14$, $p = 0.48$), indicating that our results were not a result of greater canopy cover but more litter in historically retained areas likely due to the multi-year accumulation of leaf litter into a duff layer in historically retained areas (Figure S1).

3.1 | Decomposition assay

Historical leaf litter management significantly altered teabag decay rate (k_{TBI} ; $\chi^2_{1,n=77} = 5.52$, $p = 0.01$) with 17% slower decomposition in areas where leaves were historically removed compared to areas where leaves were historically retained (Figures 3a and S2). Current management did not significantly impact teabag decay rate ($\chi^2_{1,n=77} = 0.11$, $p = 0.73$). There was no interaction between historical and current management treatments ($\chi^2_{1,n=77} = 0.03$, $p = 0.84$).

Similar patterns emerged when comparing the mass loss of teabags between historical management areas. Current management did not affect percent mass loss ($\chi^2_{1,n=154} = 0.02$, $p = 0.87$), and there was no interaction between historical and current management treatments ($\chi^2_{1,n=154} = 0.11$, $p = 0.74$). There was also no interaction between current management and tea type ($\chi^2_{1,n=154} = 0.09$, $p = 0.76$). However, there was weak evidence of an interaction between tea type and historical management ($\chi^2_{1,n=154} = 3.07$, $p = 0.07$). As expected, tea type strongly affected percent mass loss ($\chi^2_{1,n=154} = 1605.87$, $p < 0.001$), with 57% slower decomposition in

the more recalcitrant substrate of rooibos tea leaves, compared to more labile green tea leaves. While we found no differences in green tea mass loss between historical management types (Tukey test; $t = -0.74$, $p = 0.46$), rooibos tea (a more recalcitrant substrate) in historically removed areas lost 7.9% less mass than rooibos tea in historically retained areas over the same time interval (Tukey test; $t = 1.73$, $p = 0.08$) (Figures 3b and S2).

3.2 | Soil carbon

Across all samples, the percent carbon in the soil averaged $2.8\% \pm 0.15$. In March 2021, at the start of the decomposition experiment, SOC was 24% lower in areas where leaf litter was historically removed compared to areas where leaf litter was historically retained ($\chi^2_{1,n=26} = 4.8$, $p = 0.02$) (Figures 4a and S3).

After 1 or 2 years of switching from the historical management to the opposite technique (i.e., historically retain to remove or historically removed to retained), we detected no additional effect of this current year management ($\chi^2_{1,n=74} = 0.24$, $p = 0.61$), nor was there an interaction between the current and historical management types ($\chi^2_{1,n=74} = 0.05$, $p = 0.82$) on percent carbon (Figures 4b and S3). However, we continued to see evidence for differences between historical management with 16% less SOC in historically removed areas compared to historically retained areas ($\chi^2_{1,n=74} = 3.17$, $p = 0.07$).

Additionally, we found that home age was positively associated with percent carbon ($\chi^2_{1,n=26} = 4.3$, $p = 0.03$). However, the effects of historical treatment did not differ by home age (no interaction), indicating that although newer homes have less soil carbon ($\chi^2_{1,n=26} = 0.01$, $p = 0.9$), yard areas with historically retained leaves have more carbon than removed areas regardless of age (Figure 5).

4 | DISCUSSION

To examine the impacts of leaf litter removal to decomposition rates and soil carbon concentrations, we experimentally manipulated leaf litter in areas of different historical management practices. We specifically tested whether long-term litter removal would lead to persistent legacy effects even after the yard care practice had ceased. We found clear evidence of legacy effects of historical fall leaf litter management decisions on the decomposition of plant material and, ultimately, soil carbon concentrations in suburban yards. Areas where residents historically removed fallen leaves had 17% slower decomposition of a common substrate, driven by 7.9% less mass loss of the more recalcitrant litter substrate—and up to 24% less soil organic carbon compared to areas where leaves were historically retained. However, a change in current management practices, retaining or removing leaf litter for 1–2 years, had no measurable impact on decomposition or SOC. Areas where litter was historically and currently retained had almost double the amount of leaf litter from areas where litter was historically removed and currently retained. Therefore, there was a greater difference (more leaves removed)

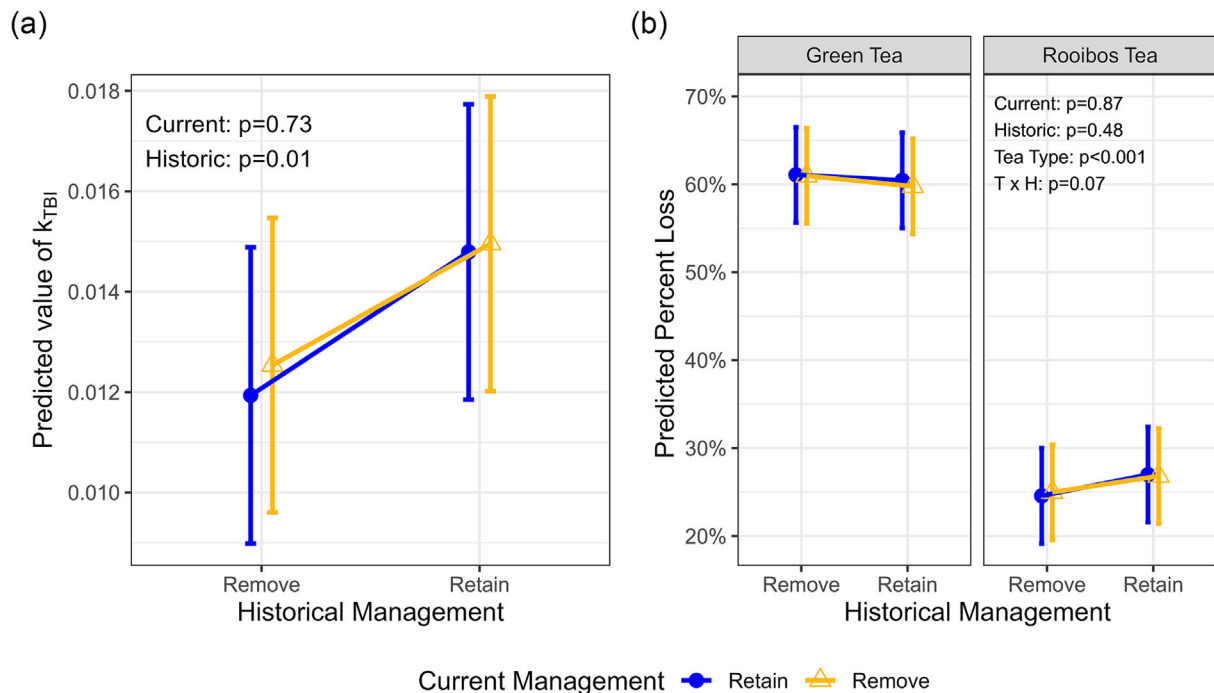


FIGURE 3 The predicted effect of current and historical leaf fall management practices on the decomposition of teabags in suburban yards in Maryland, USA. Error bars indicate standard error. (a) Predicted decay constant (k_{TBI}) for historical and current leaf fall management practices, calculated from a linear mixed model. There were no differences in predicted decay based on current management types, but historical management did play a significant role, with higher predicted decay in the retained areas regardless of current management. (b) Predicted percent mass loss of green (more labile substrate—left) and rooibos (more recalcitrant substrate—right) tea leaf litter in historical and current management treatment plots. Mass loss was higher in green tea compared to rooibos tea, but the differences in historical management effects in rooibos tea drove a tea type \times historical management interaction.

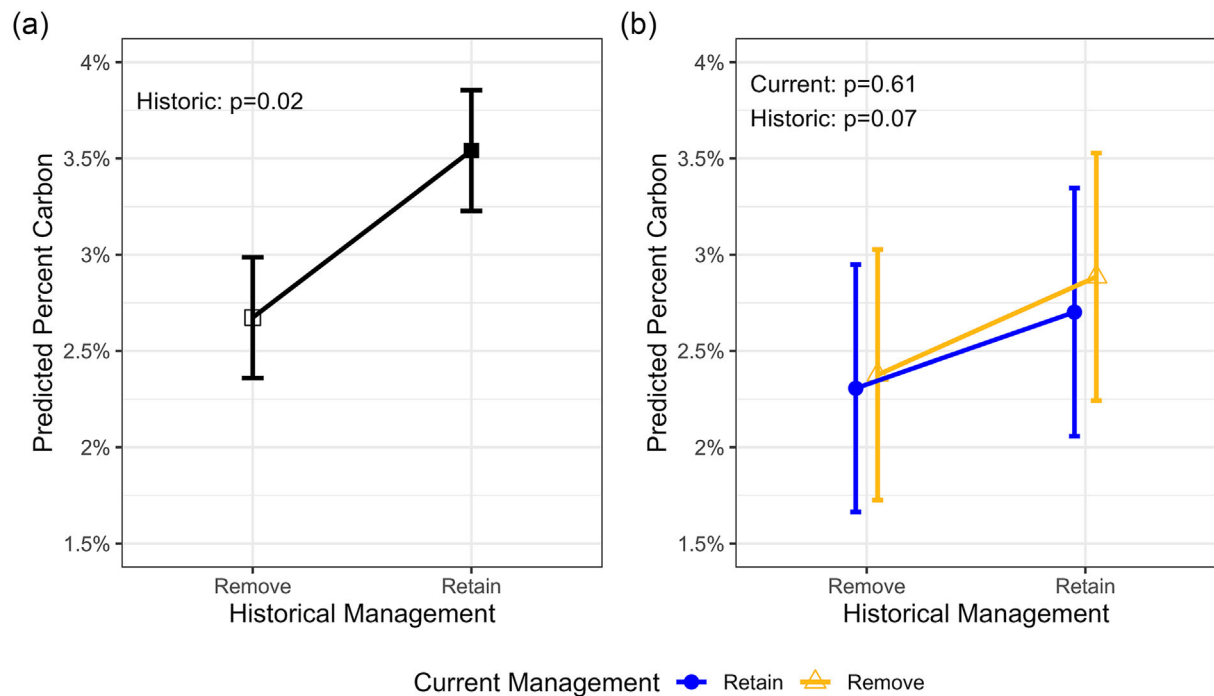


FIGURE 4 The predicted effect of current and historical leaf fall management practices on soil organic carbon (SOC) concentrations in suburban yards in Maryland, USA. Error bars indicate standard error. (a) The long-term historical removal of leaf litter reduced SOC by 24%. (b) One–two years of differing management practices did not restore SOC concentrations.

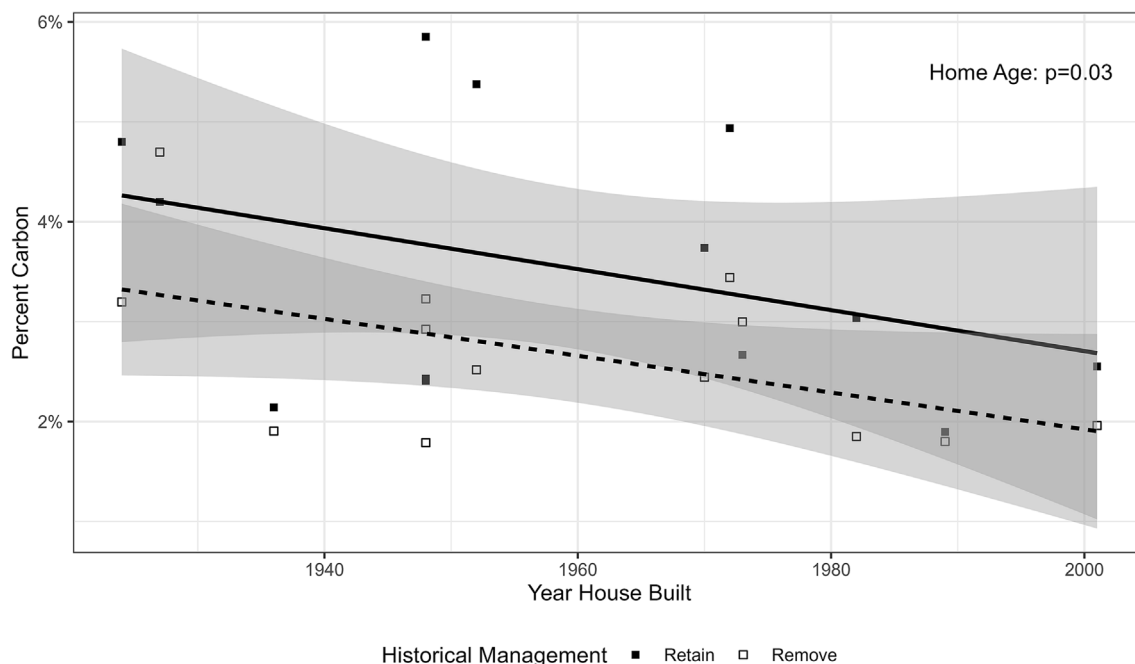


FIGURE 5 The effect of house age on soil organic carbon (SOC) concentration in Maryland, USA, under historical and current leaf fall management practices. Home age was positively associated with SOC. Error ribbons indicate standard error. The dashed trendline symbolizes historical litter removal management, while the solid trendline indicates historical litter retention.

between the current management treatments in historically retained areas. Despite this, there was still no effect of short-term management. The results of our study align most closely with our proposed hypothesis (Figure 1b) in which historical litter management effects persist despite differing current management practices. These results highlight a potentially important pathway by which consistent urban management could alter ecosystem function and suggest that changes in practices may not immediately result in altered soil processes. This has implications for soil conservation and carbon storage efforts, which may need to account for delays in regaining ecosystem function after a restoration.

We expected historical management to have greater effects than current-year management, but the magnitude of ecosystem effects in response to our historical management time frames is still notable. Similar temperate studies from forests rather than urban systems have found decomposition differences after 16 years (Kotrocó et al., 2020) and 20 years (Bowden et al., 1993; Lajtha et al., 2014). The duration of our historical removal treatments was often much shorter than these time frames, ranging from 3 to 30 years, yet we still found decomposition rate reductions. Most other studies have been carried out in forests—not suburban yards—so it could be that the paucity of plant material in yards makes decomposer communities more sensitive to changes in management. Additionally, it is important to note that we relied on participant-reported historical management durations. These durations may be underestimates if newer property owners did not know the management undertaken by previous owners.

Although both canopy cover and litter mass were greater in areas where litter had been historically retained, they were not correlated (Figure S1). Canopy cover did not directly translate to increased litter

mass. Therefore, greater litter mass in historically retained areas resulted from litter management, likely the year-on-year accumulation of organic material, and not as an artifact of greater canopy cover alone. This feedback between management, litterfall and—ultimately—decomposition and SOC, highlights how management decisions shape ecosystem outcomes.

We saw differences in decomposition rates between historical treatments, and because we used teabags that excluded macro and micro-invertebrate decomposers to measure decomposition, we can attribute those differences to changes in abiotic conditions between treatments or microbial differences between treatments. Previous research has shown that additional inputs of plant materials, including through the retention of leaf litter, can prime decomposition, whereby soil respiration increases (Xu et al., 2013), and decomposition accelerates because microbial communities are no longer carbon limited (Kuzakov, 2010). Litter addition can also increase SOC, when additional plant material leads to greater microbial storage (Bowden et al., 2014; Lajtha et al., 2018; Pisani et al., 2016). To our knowledge, leaf litter addition's effect on decomposition rate has not been tested specifically using the Tea Bag Index, though a Tea Bag Index garden study in the United Kingdom found that compost amendments increased the rate of teabag decomposition (Duddigan et al., 2020). One possible outcome of our experiment was an interactive result where the effect of current management is dependent on historical practices (Figure 1c). Retaining litter in an area where litter was historically removed could have prompted an increase in already present and locally adapted microbial populations which in turn would increase the decomposition rate of the recalcitrant tea substrate. However, we found no statistically significant interactive effect.

Standardized measures using common substrates, like the Tea Bag Index, allow for controlled comparisons across treatments and studies, but ignore a range of traits that influence decomposition of local litter, like leaf thickness, C:N ratios, lignin content, and defensive polyphenol content slowing decomposition rates (Wright et al., 2004). The Tea Bag Index relies on leaves of two types of tea—green and rooibos—with different traits. Therefore, we can assess how leaf recalcitrance impacts decomposition rates across different litter management practices by examining the mass loss of rooibos and green tea. We found that historical management decomposition differences were driven by greater decomposition of the more recalcitrant rooibos tea leaves in yard areas than historically retained leaves. Leaching, an early decomposition process drives the mass loss of the more labile green tea leaves (Djukic et al., 2018). Perhaps litter management has a greater impact on biotic processes, such as microbial decomposition, more observable in rooibos tea than abiotic processes that drive green tea (Djukic, personal communication). Additionally, it is possible that historically removed areas lack the specialized microbial communities needed to decompose rooibos tea. Removing leaves may act as a filtering effect so that only r-strategists, which are not adapted to process more recalcitrant components, can survive (Fanin et al., 2020).

Alterations to decomposition processes can alter carbon sequestration. Theoretically, faster decomposition rates lead to greater carbon mineralization, while slower rates allow for immobilization within soil aggregates and microbial necromass (Prescott, 2010; Schmidt et al., 2011). However, any increased rate of decomposition is not as important to SOC as the presence or lack of litter inputs. When leaf litter is removed, there is clear evidence that SOC content decreases (Bowden et al., 2014; Sayer et al., 2020; Xu et al., 2021). We found that areas where litter was historically removed had 24% less SOC. This underscores previous research that found unmanaged forested land adjacent to yards had greater SOC than managed areas (e.g., lawn, raised beds) (Yesilonis et al., 2016). However, we did not find any differences in SOC between short-term management practices, suggesting that management choices may take several years to accumulate to ecosystem effects. Other litter manipulation experiments in unmanaged systems have also found no effects on soil carbon after 2–5 years (Holub et al., 2005). Our results suggest that small-scale but long-term retention of leaf litter can increase SOC in yards, but management is required for more than 2 years to affect these processes. Further research is needed to pinpoint the time needed for SOC to respond to management. We did find that older homes had yards with greater SOC levels than newer homes. But, even in newer built homes, historically retaining leaves increased SOC compared to continuously removing leaves.

Given the ubiquity and scale of urban leaf litter management, it is important to understand the consequences of these decisions on soil processes that determine carbon storage and likely impact urban plant health and stormwater infiltration rates. Our study finds impacts of leaf litter removal on decomposition and carbon processes, across a range of yards, underscoring the ecosystem impacts of leaf litter removal. While we find no effect of 1–2 years of litter retention, we do find historical legacy effects after a longer duration of management. Further research

is needed to explain the variation in the legacy effect size, such that ecosystem services might be maximized, and to understand the social and cultural drivers that encourage the long-term adoption of environmentally friendly management practices. Retaining leaves in just one portion of the yard could increase soil organic carbon and decomposition and benefit other ecosystem services not studied here, such as long-term carbon sequestration, water-holding capacity, and soil fertility.

AUTHOR CONTRIBUTIONS

Karin Burghardt and Max Ferlauto acquired funding and designed the experiment. Max Ferlauto recruited homeowners and set up experimental plots. Lauren Schmitt and Max Ferlauto planned and executed the decomposition experiment. Max Ferlauto and Lauren Schmitt jointly carried out analysis and writing of the first draft of the manuscript. All authors read and revised the manuscript and approved of the final draft.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to report.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available at Figshare at [10.6084/m9.figshare.24921144](https://doi.org/10.6084/m9.figshare.24921144).

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SUPPORTING INFORMATION

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