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Research Paper

Urban forest resilience: assessment and management strategies for stressed trees in diverse environments

Jeff Dacosta Osei[1*], Zhu Ning[2], Yaw A. Twumasi[3]
[1*,2,3]Department of Urban Forestry, Environment and Natural Resources, Southern University and A&M College, Baton Rouge, LA, USA.

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ABSTRACT

A variety of trees are found in urban and wild areas, and these trees are indispensable for maintaining ecosystem health and promoting human well-being. However, stressors affect their health, requiring appropriate management approaches. In this study, stressed trees of four species at Southern University and A&M College in Baton Rouge, USA, were assessed and management measures recommended. Southern magnolia, southern red oak, and live oak showed symptoms of stress such as leaning and decay, while loblolly pine showed bark beetle infestation and resource competition. For each species, specific stress indicators were identified and management approaches recommended, including the installation of support systems, pruning of diseased branches, soil tillage, and pest control. These practices strengthen the urban forest and help ensure the continued health and functioning of its ecosystems.

Corresponding Author:
Jeff Dacosta Osei
Department of Urban Forestry, Environment and Natural Resources, Southern University and A&M College, Baton Rouge, LA, USA.
Email: jeffdacosta.osei@subr.edu

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1. INTRODUCTION

Urban landscapes, teeming with human activity, are home to many plant species, especially trees, which are important for the ecological balance of ecosystems and the quality of human life [1]. The

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Southern University and A&M College campus, in Baton Rouge, Louisiana, United States, with its spacious lawns and tall trees, is not only a centre of academic activity but also harbours considerable biological diversity. However, like any urban landscape, the campus trees face a range of stressors that limit their health and longevity, including air and soil pollution, soil compaction, pest infestations, and resource competition [2]. Their health may also be adversely affected by anthropogenic climate change, including extreme weather and increased surface temperatures [3]. As part of the city and metropolitan forest network, a healthy tree cover on campus is of paramount concern. In this study, the stressors affecting prominent tree species on the Southern University and A&M College campus and their effects on tree health were assessed, and targeted management strategies were developed to minimize their influence and secure the resilience of the campus tree population.

Assessment and management strategies for stressed trees are crucial for maintaining urban greenery and forest ecosystems, and understanding the impact of environmental stresses such as drought, pollution, and high temperatures is essential [4]. Diverse strategies are needed to address the challenges faced by urban trees, including innovative arboricultural techniques, species selection, and post-planting management [5]. Research on the relationship between transposons and environmental stress responses in plants sheds light on the genetic mechanisms of stress tolerance [6], and the Global Tree Assessment of the conservation status of tree species worldwide emphasizes the importance of prioritizing conservation efforts and effective management strategies to protect tree diversity [7]. These insights can guide the development of comprehensive strategies for assessing and managing stressed trees in diverse environments.

The species selected for this study- southern magnolia, southern red oak, live oak, and loblolly pine- represent the campus tree community well; they were chosen for their abundance on campus and their susceptibility to common urban stressors. By providing information on the challenges facing urban trees at Southern University and A&M College and developing management recommendations specific to each species, the study aims to contribute to ongoing efforts to preserve and enhance the institution's urban forest.

2. RELATED WORK

Several studies have addressed the identification, assessment, and management of tree stress. Ito [6] explored the relationship between transposons and environmental stresses in plants, concluding that this relationship varies among plant species, and even within a species different types of transposons have distinct relationships with their hosts; although transposons are typically silenced in plant genomes to prevent mutations, they can be activated by environmental stimuli, reflecting a balance between the benefits of transposon-mediated evolution and the risks of increased mutation rates. [7] Introduced a special issue of Plants, People, Planet of 13 articles examining the impact and potential of the Global Tree Assessment, which used methods including national assessments and taxonomic analyses to evaluate the conservation status of trees globally, with particular attention to regions such as Papua New Guinea and Malaysia. Their results highlight the urgency of conservation efforts in the face of widespread tree extinction risk; limitations include data deficiency in biodiverse regions and challenges in assessing threats not linked to rarity. Their proposed plant diversity conservation network outlines four primary activities—document, grow, plant, and manage-and emphasizes collaboration and technology for effective conservation amid rapid environmental change.

[4] Combined a greenhouse experiment with a soil–plant–atmosphere hydraulic model to investigate the effect of mixing a drought-avoidant (Pinus halepensis) and a drought-tolerant (Quercus ilex) species on plant water stress during extreme drought, finding a neutral effect on the drought-avoidant species and a positive effect on the drought-tolerant species in mixtures, attributed by model simulations to changes in hydraulic connections; the study's controlled environment may not fully capture the complexity of real forests. Aalipour and Nikbakht [5] examined the effects of urban environmental stress on tree mortality, highlighting small planting pits, drought, pollution, and pests, and proposed strategies such as innovative arboricultural techniques and species selection, emphasizing the need to understand

tree responses from the molecular to the ecophysiological level. Pal [8] examined the threats faced by Indian forests, including biodiversity loss, deforestation, and plastic pollution, analysing forest cover data and the impacts of wildfires, climate change, and anthropogenic activities, and highlighted the alarming rate of biodiversity decline and habitat destruction.

Building on these studies, the present study addresses the gap in understanding the specific stressors affecting tree species in urban environments and provides practical management strategies, offering concrete examples and recommendations for assessing and managing stressed trees at Southern University and A&M College, and thereby contributing to urban forest resilience.

3. MATERIALS AND METHODS

3.1 Study Area

The study was conducted at Southern University and A&M College (Figure 1), in Baton Rouge, Louisiana, USA. The city lies in the southern United States and has a humid subtropical climate with hot summers and mild winters; its location along the Mississippi River adds to the richness of the region's biodiversity and vegetation. The campus covers about 512 acres of varied landscapes, including manicured lawns, woodlands, and gardens, with a tree population ranging from large hardwood trees to ornamental shrubs and other native and introduced species [9]. The campus is bordered on the north and east by residential neighbourhoods and forms an oasis of green within the urban sprawl of Baton Rouge, with tree-lined avenues, shaded walkways, open green spaces, live oaks adorned with Spanish moss, tall pines, and flowering magnolias. It also faces the problems typical of urban environments, such as soil compaction, pollution, pest infestations, and competition for nutrients, compounded by climate change through increased temperatures and more frequent extreme weather, making it a suitable setting for investigating urban tree stressors and management strategies.

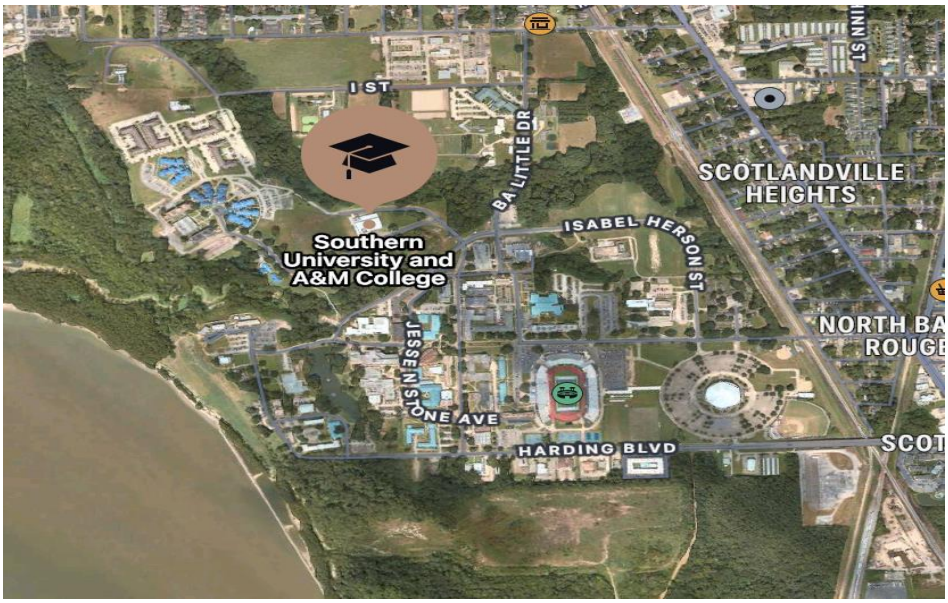

Figure 1. Map of Southern University and A&M College

3.2 Materials

Visual inspection tools such as binoculars, hand lenses, and tape measures were used to examine tree canopy structure, foliage health, and spatial relationships between trees. Diagnostic equipment, including soil testing kits and bark inspection tools, enabled assessment of soil health and bark integrity. Climbing and safety gear, including harnesses, ropes, helmets, and gloves, was used by certified arborists to access tree canopies safely for closer inspection and pruning. Notebooks, GPS devices, and digital

cameras were used to record observations, geographic coordinates, and high-resolution images, and personal protective equipment ensured the safety of the study team during fieldwork.

3.3 Methods

Representative trees of southern magnolia (Magnolia grandiflora), southern red oak (Quercus falcata), live oak (Quercus virginiana), and loblolly pine (Pinus taeda) were selected on the campus, prioritizing trees showing visual evidence of stress such as leaning, decay, pest infestation, or competition for space. The general health and condition of the selected trees were assessed by visual inspection using binoculars, hand lenses, and tape measures, surveying canopy structure, foliage health, and spatial relationships and recording the degree and spread of stress indicators in detail. To understand the causes of stress, the trunks and branches were checked with bark inspection tools for signs of decay or cavities, branches were evaluated visually and by touch to identify diseased or damaged branches for removal, and canopies were accessed with climbing gear for close inspection and pruning. High-resolution photographs documented the findings [10].

Tree species, location coordinates, stress indicators, and recommended management actions were recorded, and Google Maps was used to map tree locations and visualize stress patterns across the campus landscape [11], [12]. Following analysis of the inspection data, management strategies were developed for each tree species and stressor, ranging from support systems and pruning to soil tillage and pest control [13]. The strategies were implemented in consultation with the campus arborists and grounds maintenance staff, prioritized by the severity and urgency of the identified stressors, and adjusted over time to maintain the health and vitality of the campus tree population [13].

4. RESULTS

The results revealed varying degrees of stress among the selected trees. Each species exhibited distinct stress indicators, which were assessed and addressed through targeted management strategies, as summarized in Table *1* and illustrated in Figure *2*, Figure *3*, Figure *4*, Figure *5* and Figure *6*.

Table 1. Tree Stress Analysis and Management Strategies

Tree	Location	Stress indicators	Recommendations
Southern magnolia	30.521° N, 91.197° W	Tree is leaning; leaves turning brown	Install a support system (cables or braces) to stabilize the tree and prevent further leaning; soil tilling
Southern red oak	25.380° N, 58.990° W	Tree is leaning; a signpost is affecting its growth	Install a support system (cables or braces); remove the signpost
Live oak	19.900° N, 49.580° W	Tree is leaning; many decay spots	Install a support system (cables or braces); prune diseased or decayed branches; ensure proper drainage and avoid overwatering; monitor and treat for pests
Loblolly pine (1)	14.380° N, 49.090° W	Small holes bored by pine bark beetles, whose larvae feed on the inner bark and create tunnels, accompanied by frass and resin oozing from the holes; this weakens the tree and increases its susceptibility to disease and other stressors	Apply insecticides; remove infested branches; monitor regularly

Tree	Location	Stress indicators	Recommendations
Loblolly pine (2)	16.750° N, 33.020° W	Trees growing very close together and competing for sunlight and nutrients, causing one tree to lean; soil compacted and eroded, exposing roots	Soil tilling; erosion control; install a support system (cables or braces)



Figure 2. Southern Magnolia: Tree, Foliage, and Location



Figure 3. Southern Red OAK: Tree, Signpost Affecting Growth, and Location



Figure 4. Live OAK: Tree, Decay Spots, and Location



Figure 5. Loblolly Pine (1): Tree, Bark Beetle Damage, and Location



Figure 6. Loblolly Pine (2): Closely Spaced Trees and Location

4.1 Discussion

The study described the types of stressors experienced by major tree species on the Southern University and A&M College campus, with the aim of mitigating their impacts and enhancing the resilience and longevity of the campus trees. Although the stressors varied among species, all were exposed to several kinds, with leaning trees, browning foliage, decay spots, and pest infestations the most notable. The interaction of natural and human-induced stressors on tree health is complex [14]. All the species showed leaning, a safety hazard whose underlying causes include soil compaction, poor root anchorage, and competition for resources; installing support systems such as cables or braces is therefore a critical management measure for maintaining structural stability [15].

Diseased or decayed branches were predominant on the live oak, calling for proactive care: diseased branches should be removed, and excessive watering, which can lead to root rot, should be avoided [16]. Monitoring for pests is also important for the well-being and resilience of live oaks [16], and the presence of decay spots indicates the need to check for fungal infection or wood decay that could compromise structural integrity and longevity.

The infestation of loblolly pines by pine bark beetles illustrates the vulnerability of some tree species to insect pests, especially in urban environments [17], making insecticide application, removal of infested branches, and continuous monitoring necessary to manage beetle populations and protect the pines. Competition for sunlight and nutrients among loblolly pines indicates that attention to tree density and canopy spacing is needed to reduce stress and promote growth, and soil compaction and erosion were important stressors in the study area. Soil tilling was recommended to improve aeration, drainage, and nutrient availability, which promote root health and tree vitality [18], and erosion should be addressed through appropriate landscaping and erosion control to protect roots from exposure. This study therefore underscores the importance of proactive tree management in urban environments, together with continued monitoring and adaptive management in the face of changing environmental stressors.

5. CONCLUSION

This study offers insights into the assessment and management of stressors affecting prominent tree species on the campus of Southern University and A&M College in Baton Rouge, Louisiana, USA. Through visual inspection, diagnostic analysis, and targeted management interventions, it sought to mitigate the environmental, biological, and anthropogenic stressors affecting urban tree health. The results show variability in stress indicators among southern magnolia, southern red oak, live oak, and loblolly pine, reflecting the diversity of factors affecting tree health in urban landscapes. Leaning trees, browned foliage, decay spots, and pest infestations point to the need for proactive care, and the management practices recommended include support systems for leaning trees, pruning of diseased branches, soil tillage, pest control, and erosion control. These interventions address the root causes of tree stress, contributing to the long-term sustainability of the campus tree population, biodiversity conservation, ecosystem services, and human well-being, while monitoring and adaptive management remain integral to their effectiveness.

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Authors Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Jeff Dacosta Osei	✓	✓	✓		✓	✓		✓	✓		✓		✓	
Zhu Ning				✓	✓	✓		✓		✓				
Yaw A. Twumasi	✓						✓			✓		✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

No conflict of interest.

Informed Consent

Not Applicable.

Ethical Approval

Not Applicable.

Data Availability

This study draws on publicly available data. No new datasets were created.

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BIOGRAPHIES OF AUTHORS

	**Jeff Dacosta Osei,** is affiliated with the Department of Urban Forestry, Environment and Natural Resources at Southern University and A&M College, Baton Rouge, Louisiana, USA. His academic interests are associated with urban forestry, environmental sustainability, and natural resource management. His institutional affiliation reflects a focus on environmental and forestry-related research, contributing to the broader understanding of sustainable urban environments and responsible natural resource utilization. Email: jeffdacosta.osei@subr.edu
	Dr. Zhu Ning, is a Professor of Urban Forestry at Southern University and A&M College, Baton Rouge, Louisiana, USA. She specializes in urban forest ecophysiology, climate change assessment, environmental sustainability, and natural resource management. Her research focuses on understanding environmental challenges, developing mitigation and adaptation strategies, and promoting sustainable ecosystem management. She has extensive research experience and has contributed to numerous scientific publications, research projects, and academic initiatives in forestry and environmental sciences.
	**Yaw A. Twumasi**, is affiliated with the Department of Urban Forestry, Environment and Natural Resources at Southern University and A&M College, Baton Rouge, Louisiana, USA. His research interests include remote sensing, geographic information systems (GIS), environmental monitoring, forestry, and natural resource management. His academic work focuses on applying geospatial technologies to environmental assessment, land-use analysis, and sustainable resource management, contributing to research in environmental sciences and ecosystem conservation.