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Efficient Urban Water Management: Using Remote Sensing to Monitor and Manage Irrigated Landscape in Inland Southern California

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Introduction

Managing irrigated landscapes in urban areas presents unique challenges due to their complexity and diversity. First, the plant types are highly diverse, ranging from turfgrass species to shrubs, ground covers, and trees, each with distinct physiological traits, water requirements, and drought tolerance mechanisms. Second, the scale of managed areas varies widely—from small residential yards to urban parks, roadways, landscapes maintained by homeowners' associations, and recreational areas such as sports fields and golf courses.

Regular field scouting is necessary to identify drought stress and detect irrigation system issues such as clogged or broken valves and pipes, which helps improve water use efficiency and reduce water loss. However, this process is both time-consuming and labor-intensive, which often leads to delays in detecting under- or over-irrigation and repairing broken irrigation components—resulting in water waste, runoff, and sometimes damage to plants and trees.

Remote sensing can help monitor irrigated urban landscapes rapidly without disturbing plants or soil, but the most appropriate technology depends on the size of the landscape and the management goals. At the city or regional scale, satellite imagery is the most practical option because it covers large areas and helps identify where vegetation is present, where irrigation is likely occurring, and how plant health varies across neighborhoods. This information can support water agencies and municipalities in estimating irrigated area and overall landscape water use. For larger managed landscapes, such as parks and golf courses, drones provide more detailed imagery and greater flexibility. Drone flights can be scheduled when needed to detect early signs of drought stress and irrigation problems and to evaluate how irrigation systems are operating. At smaller scales, such as nursery production in pots, small research plots, or residential landscapes, simpler handheld tools or even images captured by cell phones are often more practical and affordable. In practice, remote sensing includes a range of tools, and the choice depends on landscape size, available resources, and how frequently and how much detail is needed. When used appropriately, these technologies can improve irrigation efficiency, detect problems early, and support more sustainable urban water management.

This publication highlights practical applications of remote sensing for urban landscape management and provides threshold values for assessing aesthetic quality and overall plant health in eighteen landscape species commonly used in inland Southern California, based on nearly a decade of field trials.

What is remote sensing?

Remote sensing is the science of studying objects from a distance without physical contact, offering a fast and nondestructive approach. Scientists have long used remote sensing to study a wide range of natural phenomena and environments. Satellite and airborne remote sensing are typically used to map large-scale areas. More recently, drone-based remote sensing has gained popularity across various sectors due to its ease of use and accessibility (Sapkota et al. 2023b, 2024).

For monitoring the health and growth of landscape plants, remote sensing with handheld sensors is also common, offering time and cost savings and producing more consistent results than traditional visual ratings by trained observers. Drone-based remote sensing is often used to generate maps, making it an efficient tool for identifying plant health and growth conditions across different locations, with field scouting used as a follow-up when issues are detected.

Remote sensing can also detect drought injury and water stress before symptoms become visible to the human eye, giving landscape managers time to address underlying issues. This early detection is critical for maintaining the aesthetic quality of urban landscapes. Previous research has shown that drone-based remote sensing detected drought stress more than 5 days before it was noticeable to humans (Hong et al. 2019).

Plant canopy temperature can also be monitored using thermal cameras mounted on drones. Canopy temperature provides valuable insights into plant stress levels, environmental cooling potential, and plant water use (Verdi et al. 2024; Sapkota et al. 2023a).

Normalized difference vegetation index

Remote sensing sensors and cameras typically measure light reflectance from the plant canopy at different wavelengths. Scientists have developed a wide range of vegetation indices by combining reflectance data from different spectral bands to assess plant growth and health. The Normalized Difference Vegetation Index (NDVI) is the most widely used index for monitoring overall plant health and is calculated based on the difference between red and near-infrared reflectance values (fig. 1).

NDVI values for vegetation typically range from 0 to 1, with higher values indicating greener and healthier plants. In urban landscapes, NDVI has proven to strongly correlate with visual ratings of various landscape species (Bremer et al. 2011a, b; Sapkota et al. 2023c), suggesting its potential as a replacement for visual assessments of aesthetic quality. This replacement is important for developing minimum irrigation recommendations that sustain plant aesthetic value with reduced water use quickly and consistently.

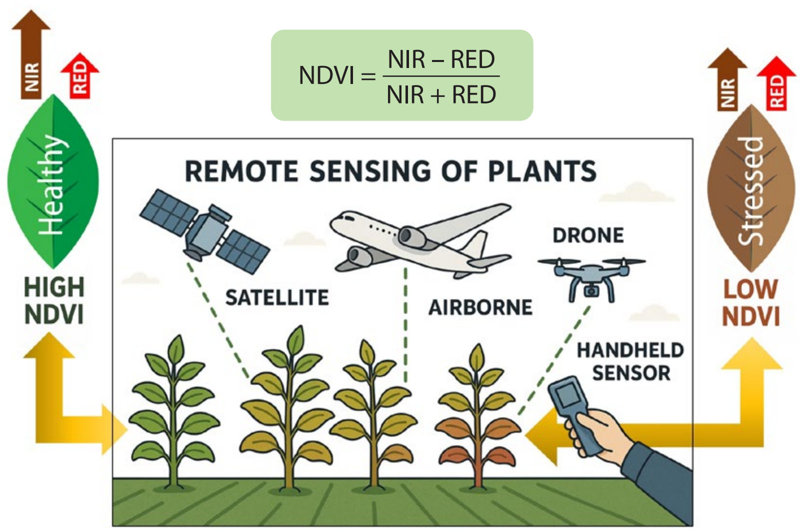

Figure 1. Various remote sensing platforms and tools can be used to monitor the health of urban landscape plants using vegetation indices, such as the NDVI.

Figure 2. Students from the Verdi Water Management Group collect NDVI and canopy temperature data from groundcover species at the UCR Agricultural Experiment Station using handheld sensors (left), and from turfgrass plots at the South Coast Research and Extension Center using a drone equipped with multispectral and thermal cameras.

Figure 3. Landscape species evaluated in field trials conducted in inland Southern California.

However, our research shows that NDVI thresholds vary by species and should therefore be established separately for each one (Iradukunda and Verdi 2024; Haghverdi et al. 2023; Sapkota et al. 2023c; Haghverdi et al. 2021a, b, c). Once NDVI thresholds are established for a species, they can be used for rapid field scouting across large areas to identify locations where plants may be experiencing stress.

Remote sensing for urban landscape management

Our published research explores a wide range of applications for handheld and drone-based remote sensing for managing urban landscapes, from plant performance to environmental parameters (fig. 2). We have monitored the effects of limited irrigation on turfgrass (Haghverdi et al. 2021a, b, c; Haghverdi et al. 2023) and vegetative ground covers (Sapkota et al. 2023c). In similar studies, the effects of recycled water on salinity and drought stress were measured on turfgrass (Singh et al. 2024). Regarding weather and soil data, we have used drones to measure soil moisture and carbon dioxide emissions from turfgrass under different irrigation strategies (Iradukunda and Verdi 2024; Iradukunda et al. 2026). In vegetative ground covers, we estimated water use (Amiri et al. 2025; Amiri and Verdi 2025) and assessed how water conservation affects the cooling potential of various landscape species (Verdi et al. 2024; Sapkota et al. 2023a).

A total of eighteen landscape species (fig. 3) were studied over approximately 10 years in multiple field trials conducted at the UC Riverside Agricultural Experiment Station (Iradukunda and Verdi 2024; Singh et al. 2024; Verdi et al. 2024; Haghverdi et al. 2023; Sapkota et al. 2023b, c; Haghverdi et al. 2021a, b, c). Details of the studies conducted at UC Riverside are provided in table 1. The selected species included four turfgrasses and fourteen drought-tolerant ground covers, chosen in collaboration with local nurseries. The ground covers

Table 1. Details of the field research trials conducted in Riverside

Crop type	Duration	Reference
Hybrid bermudagrass and tall fescue	2017–2019	Haghverdi et al. 2021c, 2023
Ten groundcover species	2020–2021	Sapkota et al. 2023 b, c
St. Augustine and buffalo grass	2021–2023	Iradukunda et al. 2026; Iradukunda and Verdi 2024
Four groundcover species	2022–2023	Amiri et al. 2025; Amiri and Verdi 2025

Table 2. NDVI thresholds for eighteen landscape species studied under the semiarid conditions of inland Southern California. These thresholds can be used to assess minimum aesthetic quality and detect early signs of plant stress

	Common name	Scientific name 'cultivar'	Origin	NDVI
1	Creeping Australian saltbush	*Rhagodia spinescens*	Australia	0.46
2	Coyote bush	*Baccharis* × 'Starn'	USA	0.41
3	Gold emu bush	*Eremophila glabra* 'Mingenew Gold'	Australia	0.50
4	Honeysuckle	*Lonicera japonica*	Asia	0.47
5	Ice plant	*Ruschia lineolata* 'Nana'	South Africa	0.48
6	Jasmine	*Trachelospermum jasminoides*	China	0.53
7	Lantana	*Lantana montevidensis*	South America	0.50
8	Rosemary	*Rosmarinus officinalis* 'Roman Beauty'	Mediterranean	0.50
9	Saltillo evening primrose	*Oenothera stubbei*	Mexico	0.44
10	Buckwheat	*Eriogonum fasciculatum* 'Warriner Lytle'	USA	0.40*
11	Prostrate acacia	*Acacia redolens* 'Low Boy'	Australia	0.39
12	African daisy	*Arctotis acaulis* 'Big Magenta'	South Africa	0.26
13	Vaalbietou	*Chrysanthemoides incana*	South Africa	0.29
14	Kurapia	*Lippia nodiflora*	Japan	0.40
15	Hybrid bermudagrass	*Cynodon dactylon* × *C. transvaalensis* 'Tifgreen'	USA(cultivar)	0.60
16	Tall fescue	*Festuca arundinacea* 'Westcoaster'	USA(cultivar)	0.70
17	Buffalograss	*Buchloë dactyloides* 'UC Verde'	USA(cultivar)	0.43
18	St. Augustinegrass	*Stenotaphrum secundatum* 'A–G'	USA(cultivar)	0.54

*No minimum NDVI threshold was established for buckwheat by experimental data showing that NDVI > 0.4 is visually acceptable.

represented a mix of native plants, widely used non-natives, and newly introduced species suitable for the hot, dry conditions of inland Southern California. The research team collected remote sensing data throughout the study periods using both handheld sensors and drones equipped with multispectral and thermal cameras across plots exposed to different irrigation treatments.

Table 2 summarizes the NDVI thresholds for all selected species. These thresholds were determined by directly comparing visual ratings from trained observers with NDVI values collected at the same time using a handheld NDVI sensor. The NDVI threshold represents the minimum acceptable value for each species. Values below this threshold indicate plant stress and aesthetic quality below the standard expected in urban landscapes. In other words, NDVI values below the thresholds correspond with visual rating scores that fall below the minimum acceptable quality for urban settings. Because NDVI thresholds vary by species, no single value can be applied universally, highlighting the importance of research-based data such as those presented in this publication for the reliable use of remote sensing in urban landscape management. More information about irrigation management and the potential environmental cooling benefits of these plant species is available on Dr. Verdi's research website.

Summary and conclusion remarks

Remote sensing is a fast and nondestructive method for monitoring the health and growth of urban landscape species. Drone-based remote sensing is gaining popularity due to its ease of use, flexibility in camera types, and ability to rapidly collect data over large areas.

The NDVI is a widely used vegetation index derived from remote sensing data that indicates plant greenness and overall health. This publication provides research-based NDVI thresholds for a variety of landscape species commonly used in inland Southern California, which can aid in performance monitoring.

Additional information about landscape irrigation management and remote sensing for inland Southern California—including updates on species currently under evaluation—is available on Dr. Verdi's research website.

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