[DA-029] GIS&T in Landscape Architecture

Abstract

GIS and landscape architecture share a profound, co-evolving relationship that dates back to the 1960s, when the foundational concept of spatial data layers was first conceived. Since then, GIS has evolved into many applications that support the entire landscape architecture workflow, encompassing data acquisition, site analysis, design research, data visualization, and landscape performance assessment. Beyond providing an evidence-based approach to promote environmental sustainability and resilience, GIS is increasingly instrumental in addressing complex socioeconomic challenges, including landscape justice and public health. By leveraging new advanced technologies—such as the Landscape Information Model (LIM) and Digital Landscape Twin (DLT)—the profession is uniquely empowered by GIS to fulfill its core mission: fostering equity, democracy, sustainability, and resilience within the ever-evolving human-landscape relationship.

Keywords: geodesign

Author & citation

Huang, G. (2026). GIS&T and Landscape Architecture. The Geographic Information Science & Technology Body of Knowledge (Issue 2, 2026 Edition), John P. Wilson (Ed.).
DOI: 10.22224/gistbok/2026.2.1

Explanation

1. Definitions
2. A Brief History of Coevolving
3. A GIS-enabled Workflow in Landscape Architecture
4. Landscape Ecology
5. Human-landscape Interactions
6. Sustainability and Resilience
7. Landscape Information Model
8. From Geodesign to Digital Landscape Twins

1. Definitions

- **Landscape Architecture**: Landscape architecture is the study and practice of analyzing, planning, and designing the land and related living systems through the integration of ecological science, sociocultural theory, and technical engineering to create sustainable and resilient built environments.

- **Landscape Ecology**: Landscape ecology is the study of how spatial patterns and structures of a landscape affect ecological functions and processes.

- **Landscape Justice**: Rooted in the theory of spatial justice—which advocates for the equitable distribution of spatial resources—landscape justice is the

equitable distribution of the ecological, health, and sociocultural benefits of the physical environment.

- **Landscape Information Model (LIM):** LIM is a data-rich, digital abstraction of the living outdoor environment—including its topography, vegetation, soil types, and water systems.

- **Digital Landscape Twin (DLT)**: Digital Landscape Twin is the "living, breathing" version of the LIM. It mirrors the processes and changes in physical landscape by a constant stream of digital data and simulations

2. A Brief History of Coevolving

The early development of Geographic Information Systems (GIS) was inextricably linked to the field of landscape architecture, forming a symbiotic relationship where design needs spurred technological innovation. The conceptual breakthrough arrived with Ian L. McHarg's seminal 1969 book, Design with Nature, which introduced a systematic method of overlaying transparent maps of soils, hydrology, vegetation, and environmental hazards. By stacking these thematic layers to determine land suitability, McHarg established the logical framework for what would become digital "data layers" in GIS. As computing power advanced throughout the 1960s and 1970s, these thematic overlays were transformed into digital spatial data layers, providing the building blocks for later GIS development. Some of the earliest deployments of functional GIS systems, such as CGIS (the Canada Geographic Information System) and EPPL (the Environmental Planning and Programming Language) in Minnesota, were designed to solve practical environmental and land-use problems, such as assessing the potential of rural land and mapping critical factors including soil quality, agriculture, forestry, and wildlife habitats.

This shift from static mapping to dynamic spatial analysis was later accelerated at the Harvard Laboratory for Computer Graphics and Spatial Analysis (1965–1991). Many foundational programs, including GRID for suitability modeling and SYMVU for 3D visualization, were developed specifically to meet the practical demands of environmental planning and landscape architecture projects (Chrisman, 2006). The laboratory functioned as a key intellectual and technical incubator for a few landscape architecture graduate students who subsequently founded or led influential GIS companies, including the Environmental Systems Research Institute (ESRI) and the Earth Resources Data Analysis System (ERDAS). The software platforms developed by these companies—most notably ArcGIS and ERDAS IMAGINE—have become foundational commercial tools in GIS and remote sensing.

Additional hubs of GIS development included the University of Illinois, where the landscape architecture program—through collaborations with the U.S. Army Corps of Engineers—contributed to the development of GRASS GIS, and Utah State University, whose landscape architecture program played a pioneering role in applying GIS to outdoor recreation planning and land management in the western United States. Other influential universities, including the University of Georgia and the University of Wisconsin, further

advanced the adoption and dissemination of GIS within landscape architecture education and practice in the early years.

Collectively, these efforts underscore the significant role of landscape architecture as both an intellectual and applied driver in the early GIS development. Challenges from landscape practices provided the functional requirements that drove the development of computational tools, while landscape architects and planners were among the first to recognize the value of synthesizing ecological, infrastructural, and social information across multiple scales. This rapid adoption in the following decades transformed the profession, moving it toward a data-driven approach that remains the standard for modern landscape architecture.

3. A GIS-enabled Workflow in Landscape Architecture

Today, GIS has evolved into many applications that support the entire landscape architecture workflow, seamlessly bridging data acquisition, spatial analysis, design visualization, and landscape construction.

The persistent professional need for the accurate representation of terrain, vegetation structure, and built form has been met by contemporary field data collection techniques in GIS. Technologies such as GNSS, drones, and LiDAR allow practitioners to capture site-specific details with unprecedented precision. These high-resolution datasets are frequently integrated with authoritative regional sources on soils, hydrology, climate, and land cover to create sophisticated, multiscale, multilayered site models for visualization and analysis. Furthermore, the inclusion of time-enabled spatial data allows practitioners to move beyond static snapshots, enabling the study of seasonal landscape patterns.

On the analytical front, GIS enables the calculation of primary and secondary land parameters essential for site reconnaissance (Wilson & Gallant, 2000). Landscape architects employ a wide range of computational tools in design research, including multi-criteria suitability and constraint assessments, hydrologic and erosion modeling, and habitat connectivity analysis. By utilizing these functions, designers can identify environmental opportunities and limitations while testing various design scenarios against specific ecological and social criteria (Hanna, 1999). Specialized tools, such as line-of-sight and viewshed analysis, further allow for the evaluation of a project's visual impact on the surrounding landscape.

Because visualization is central to landscape practice, GIS provides an expansive suite of visual communication options. For example, landscape architects have explored methods for integrating GIS analysis and mapping with community planning to better capture place-specific public goals and spatial priorities (Thompson et al., 2011). This framework helped systematically map and address the spatial distribution of community priorities. Designers can create map series for presentation, or transition from two-dimensional analytical maps to immersive three-dimensional scenes and time-based animations that illustrate change. Increasingly, web-based representation and interactive visualization are used to bridge the communication gap, allowing clients and stakeholders to engage with design alternatives in a transparent, data-driven environment.

4. Landscape Ecology

Landscape ecology serves as a critical sub-discipline of ecology that focuses on the reciprocal relationship between spatial patterns—specifically the configuration of habitat patches, corridors, and edges—and ecological processes across heterogeneous geographic areas . Unlike site-specific ecological studies, this field emphasizes the "landscape mosaic," analyzing how the composition and configuration of land cover types influence the flow of energy, nutrients, and species(Forman, 1995). Consequently, landscape ecology provides the essential scientific evidence for contemporary landscape architecture, transforming design from a purely aesthetic endeavor into a functional intervention capable of improving ecological integrity.

The inherently spatial nature of this discipline has led to a deep integration with GIS, which provides the essential framework for complex landscape analysis. A suite of quantitative tools has also been devised using GIS to evaluate landscape metrics, such as the Large Patch Index or Edge Density, which allow researchers to objectively assess the ecological quality and fragmentation levels of a territory (McGarigal et al., 2012). These metrics provide a standardized language for evaluating how human-induced changes affect the "matrix" of the natural environment.

Analytical models have been developed to simulate intricate ecological flows. A primary example is the Minimum Resistance Model (also known as Least-Cost Path analysis), which is used to model animal migration by calculating the ecological resistance associated with moving through various land-use types (Knaapen et al., 1992). By quantifying these movement barriers, landscape designers and planners can identify and protect critical habitat "stepping stones" that maintain species population stability. Furthermore, strategic spatial models—such as the Ecological Security Pattern—have been developed using GIS to guide large-scale conservation projects (Yu, 1996).

5. Human-Landscape Interactions

Human–landscape interaction lies at the core of landscape architecture, as the profession seeks to shape environments that are not only ecologically sound but also meaningful and visually engaging for people. Under the National Environmental Policy Act (NEPA), federal agencies are required to evaluate the environmental consequences of major federal actions, within which visual impact analysis (VIA) and visual preference assessment constitute integral components of the review process. GIS allows landscape architects to model visibility, simulate design scenarios, and analyze how people experience and value landscapes, effectively linking spatial data with human perception (Palmer, 2019). This integration supports more informed, transparent, and responsive design decisions, reinforcing the profession’s ability to address the dynamic relationship between people and the landscapes they inhabit.

As the profession of landscape architecture evolves, its scope has expanded beyond ecological restoration and aesthetic design to encompass the complex socioeconomic dimensions of the built environment. Learning from the concept of spatial justice that argues for equitable distribution of spatial resources, landscape architects are tasked to advocate for landscape democracy, landscape justice, and strive to correct historical biases. In other words, all communities, regardless of socioeconomic status, are equally

protected from environmental hazards, and have an equal voice in the design and management of their shared landscape resources.

In this context, GIS have become indispensable for identifying spatial injustices and quantifying human-landscape interactions. A primary exemplary application is the mitigation of the Urban Heat Island (UHI) effect. Researchers utilize GIS-based thermal mapping and canopy cover analysis to quantify shade and heat exposure at the neighborhood scale. These spatial models reveal "thermal inequities," where marginalized communities often inhabit areas with higher impervious surface ratios and fewer cooling "green lungs" (Hoffman et al., 2020). By layering demographic data with heat maps, landscape architects can strategically prioritize green infrastructure investments in the most vulnerable urban areas to ensure climatic safety is treated as a fundamental human right.

Furthermore, the intersection of landscape architecture and public health has been significantly advanced through GIS modeling. Spatial analysis is now used to examine specific health risks—such as respiratory issues, mental health challenges, and cardiovascular disease—posed by the built environment. For example, GIS allows for the mapping of "greenness exposure," enabling researchers to correlate proximity to parks with measurable improvements in mental health and cognitive function (Jiang et al., 2025). Additionally, spatial tools can model the capacity of urban tree canopies to filter particulate matter and pollutants, providing a quantitative basis for using vegetation to improve air quality. By integrating these health-centric datasets, landscape practitioners can design "therapeutic landscapes" that actively combat the chronic stressors of urban life while dismantling geographic barriers to wellness.

6. Sustainability and Resilience

Beyond the ideals of equity and democracy, 21st-century landscape architects strive to foster sustainability and resilience in a world increasingly threatened by environmental degradation and climate change. That is why the post-occupancy evaluation and long-term performance monitoring of built landscapes using GIS becomes critical. This shift transforms GIS from a static mapping tool into a dynamic instrument for validating sustainability and resilience goals.

GIS provides a vital "thread of continuity" across the design, construction, and long-term management phases. For example, Yang (2018) utilized GIS to measure the landscape performance of The Woodlands, Texas, designed by Ian McHarg in the 1970s. By employing hydrological analysis and thermal mapping, Yang demonstrated that the original design successfully mitigated flooding and urban heat island effects. Such comparisons between "as-designed" and "as-built" performance data allow the profession to close the feedback loop, refining future design standards based on empirical success.

Simultaneously, landscape managers can leverage longitudinal satellite and drone imagery, LiDAR, and in-situ soil moisture sensors to monitor project performance in real time. This continuous data collection supports evidence-based adaptive management, ensuring that built landscapes successfully deliver critical ecosystem services throughout their entire lifecycle.

7. Landscape Information Model

The evolution of Building Information Modeling (BIM) has fundamentally reshaped the AEC (Architecture, Engineering, and Construction) industry, particularly as it begins to merge with GIS to provide a multiscale view of the built environment. Because traditional BIM often fails to capture the organic and temporal complexities of natural systems, landscape architects have proposed the Landscape Information Model (LIM). LIM moves beyond simple 3D geometry to represent the physical, functional, and ecological characteristics of a site. By incorporating parametric data on topography, hydrology, and vegetation, LIM potentially supports landscape performance assessments using key indicators such as water consumption, carbon sequestration and cost for construction and maintenance.

Current research themes within the LIM domain are diverse, focusing heavily on the theoretical framework, development of standards and guidelines to ensure interoperability between disparate software platforms. Despite its clear potential, LIM's industry-wide adoption faces significant systemic barriers. Primarily, current BIM software—engineered for static vertical architecture—struggles to represent the organic, non-linear growth patterns of living systems. This limitation is compounded by time; landscapes require complex temporal dimension to account for seasonal changes and ecological succession, which traditional frameworks cannot yet handle. Furthermore, the logistical challenge of specialized software, the absence of a data standard specifically for landscape elements, and the immense scale of environmental data present massive hurdles for interoperability and full adoption in the industry.

8. From Geodesign to Digital Landscape Twin

Despite the undeniable importance of GIS in this field, an increasing number of landscape architects are choosing to process spatial data through parametric design tools like Grasshopper (a visual programming environment for Rhinoceros 3D). While these tools enable the creation of dynamic, rule-based designs, they often operate within an arbitrary coordinate system. Consequently, this shift has diminished the discipline's broader exploration of traditional GIS, which emphasizes the interaction between real-world coordinates and rich spatial analysis (Walliss & Rahmann, 2016). In response to this disconnect, ESRI championed the concept of Geodesign, renewing the profession's emphasis on designing within geographic space using geospatial technologies.

Concurrently, Steinitz (2012) adapted his foundational 1990s educational framework for landscape architecture into a comprehensive methodology for Geodesign to be used in broader spatial decision-making. Many traits and characteristics of this six-model (Representation, Process, Evaluation, Change, Impact, and Decision) framework of geodesign are echoed by another emerging concept of Digital Landscape Twin — a dynamic, virtual replica of a physical landscape that can be continuously updated with real-time data and simulation. Both methodologies argue for building a spatial representation with rich spatial data, and a feedback loop to reveal consequences of design choices with spatial simulations to support smarter, data-driven spatial decision-making.

Therefore, the co-evolving relationship between GIS and landscape architecture continues

to deepen in the new millennium. The emergence of the Digital Landscape Twin—equipped with advanced, real-time, high-definition spatial data and simulation—serves as a powerful diagnostic and predictive tool to aid future landscape architecture practice (Huang, 2024). Ultimately, these advanced technologies empower landscape architecture to fulfill its core mission: bringing equity, democracy, sustainability, and resilience to the ever-evolving relationship between humans and their environments (Landscape Architecture Foundation, 2017).

References

Chrisman, N. R. (2006). Charting the Unknown: How Computer Mapping at Harvard became GIS. Redlands, California: ESRI Press.

Forman, R. T. T. (1995). Land Mosaics. Cambridge: Cambridge University Press.

Hanna, K. C. (1999). GIS in site design: New tools for design professionals. John Wiley & Sons.

Hoffman, J. S., Shandas, V., & Pendleton, N. (2020). The effects of historical housing policies on resident exposure to intra-urban heat: A study of 108 US urban areas. Climate, 8(1), Article 12.

Huang, G. (2024). Towards a digital landscape twin: Insights from the healthcare industry. Journal of Digital Landscape Architecture, 9, 873–880.

Jiang, B., Li, J., Gong, P., Webster, C., Schumann, G., Liu, X., & Suppakittpaisarn, P. (2025). A generalized relationship between dose of greenness and mental health response. Nature Cities, 2(8), 739–748.

Knaapen, J. P., Scheffer, M., & Harms, B. (1992). Estimating habitat isolation due to landscape resistance. Landscape and Urban Planning, 23(1), 1–16.

Landscape Architecture Foundation. (2017). The new landscape declaration: A call for action for the 21st century. Rare Bird Books.

McGarigal, K., Cushman, S. A., and Ene, E. (2012). FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps. Computer software program produced by the authors at the University of Massachusetts, Amherst.

Palmer, J. F. (2019). The contribution of a GIS-based landscape assessment model to a scientifically rigorous approach to visual impact assessment. Landscape and Urban Planning, 189, 80–90.

Steinitz, C. (2012). A Framework for Geodesign: Changing Geography by Design. Redlands, CA: Esri Press.

Thompson, A. W., Prokopy, L. S., Floress, K., & Weinkauf, D. C. (2011). A Method for Incorporating Community Priorities into GIS: Challenges, Choices, and Directions for Landscape Planners. Landscape Journal, 30, 299-312.

Walliss, J., & Rahmann, H. (2016). Landscape architecture and digital technologies: Re-conceptualising design and making (1st ed.). Routledge.

Wilson, J. P. & Gallant, J. C., Eds. (2000). Terrain Analysis: Principles and Applications. John Wiley & Sons.

Yang, B. (2018). Landscape performance: Ian McHarg's ecological planning in The Woodlands, Texas. Routledge.

Yu, K. (1996). Security patterns and surface model in landscape ecological planning. Landscape and Urban Planning, 36(1-3), 1–17.